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THE 1983 SPC/IREAPS TECHNICAL SYMPOSIUM

VOLUME I

SHIP PRODUCTION COMMITTEE/INSTITUTE FOR RESEARCH AND ENGINEERING FOR AUTOMATION AND PRODUCTIVITY IN SHIPBUILDING

Improving Shipbuilding Productivity

AUGUST 23,24,25,1983
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PROCEEDINGS

The Westin Hotel
Copley Place
Boston, Massachusetts

August 23-25,1983

PREFACE

IREAPS is an independent not-for-profit membership corporation founded in April 1981 to direct the 10 year-old REAPS Program. The IREAPS Program is a U.S. shipbuilding industry/Maritime Administration cooperative effort whose goal is the improvement of shipbuilding productivity through the application of computer aids and production technology.

The Tenth Annual IREAPS Technical Symposium, held August 23-25, 1983 in Boston, Massachusetts, represents one element of the IREAPS Program which is designed to provide industry with the opportunity to review new developments in shipyard technology.

The Symposium highlighted all aspects of the National Shipbuilding Research Program (NSRP) in that presentations were made by all the panel chairmen of the SNAME Ship Production Committee.

The 1983 IREAPS Technical Symposium Proceedings contain the papers presented at the meeting. The agenda in Appendix A indicates topics and speakers; Appendix B is a list of symposium attendees.

Many thanks to all those who have contributed to the success of this year's Symposium.

Pamela M. Slechta

Pamela M. Slechta
General Chairman
1983 IREAPS Technical Symposium

IIT RESEARCH INSTITUTE

1983

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KEYNOTE ADDRESS
THE HUMAN SIDE OF TECHNOLOGY

Admiral Hyman George Rickover, U.S.Navy
The Admiral H.G. Rickover Foundation
McLean, Virginia

Hyman George Rickover was born on January 27, 1900. He attended John Marshall High School, Chicago, Illinois, before his appointment in 1918, from the State of Illinois, to the United States Naval Academy, Annapolis, Maryland. He was graduated on June 2, 1922, and commissioned Ensign on June 3, 1922; subsequently he advanced, attaining the rank of Rear Admiral on July 1, 1953 and Vice Admiral as of October 24, 1958, and promoted to Admiral on the retired list on December 3, 1973, to rank from November 16, 1973. He retired from the United States Navy on January 19, 1982, after 64 years of service.

In February 1983 the Admiral H. G. Rickover Foundation was established. The purpose of the Foundation is as follows:

1) An annual Summer Science Institute attended by talented youth from the the United States and abroad.

2) Sponsorship of colloquia on education, energy, and the international flow of technology.

Formal announcement of the Foundation was made at a Tribute held in Washington, D.C. Among those present at the Tribute were our three former Presidents: Nixon, Ford and Carter. The three Presidents accepted honorary memberships on the Board of Trustees of the Foundation. All spoke of the Admiral's achievements.

ABSTRACT

The use of technology profoundly affects the shape of our society. Technology makes obsolete our traditional concepts of ethics and morals, we are pressured by technology to alter our lives without attempting to control it. Much harm has been done to man and nature because technologies have been used with no thought for the possible consequences of their interaction with nature.

Science, being pure thought, harms no one; therefore it need not be humanistic. But technology is action - - often potentially dangerous action, based on knowledge. To make technology safe, we must have protective laws and a more responsible thinking among those who manage technologies. Every citizen is duty bound to make an effort to understand how technology operates and what its possibilities and limitation are. All this is necessary if we are to achieve a humanistic attitude toward technology - - an attitude that looks upon technology as an instrument created for no other purpose - than to serve man.

A HUMANISTIC TECHNOLOGY

BY

_ ADMIRAL H. G. RICKOVER

GIVEN AT THE SHIP PRODUCTION COMMITTEE/IREAPS

AT THE WESTIN HOTEL, COPLEY PLACE

IN BOSTON, MASSACHUSETTS

TUESDAY, 23 AUGUST 1983

TODAY, I WILL OFFER FOR WHAT THEY ARE NORTH, MY THOUGHTS GAINED IN 50 YEARS OF WORK WITH TECHNOLOGY. THEY MAY HAVE RELEVANCE TO YOUR PROBLEMS.

THE IMPACT OF TECHNOLOGY ON INDIVIDUALS AND ON SOCIETY IS PROFOUNDLY AFFECTED BY THE ATTITUDE OF THE PUBLIC, AND OF ITS LEADERS, TOWARD TECHNOLOGY; THAT IS, BY THE PREVAILING CONCEPTS OF WHAT TECHNOLOGY IS AND WHAT PURPOSE IT SHOULD SERVE. SINCE TECHNOLOGY CAN BE USED IN WAYS THAT ARE HARMFUL, THIS VIEWPOINT SHOULD BE REPLACED BY A HUMANISTIC ATTITUDE--AN ATTITUDE THAT LOOKS UPON TECHNOLOGY AS AN INSTRUMENT CREATED FOR NO OTHER PURPOSE THAN TO SERVE MAN.

TECHNOLOGY IS TOOLS, TECHNIQUES, PROCEDURES, THINGS; THE ARTIFACTS FASHIONED BY MODERN INDUSTRIAL MAN TO INCREASE HIS POWERS OF MIND AND BODY. WE ALONE BEAR RESPONSIBILITY FOR OUR TECHNOLOGY. IN THIS, AS IN ALL OUR ACTIONS, WE ARE BOUND BY THE PRINCIPLES GOVERNING HUMAN BEHAVIOR IN OUR SOCIETY. THESE ARE NOT ONLY PERSONAL, BUT SOCIAL AS WELL.

THESE PRINCIPLES CANNOT BE OVEREMPHASIZED, FOR THE NOTION IS WIDESPREAD THAT, HAVING WROUGHT VAST CHANGES IN THE MATERIAL CONDITIONS OF LIFE, TECHNOLOGY MAKES OBSOLETE OUR TRADITIONAL CONCEPTS OF ETHICS AND MORALS, AS WELL AS ACCUSTOMED WAYS OF ARRANGING POLITICAL AND SOCIAL RELATIONSHIPS. EARNEST DEBATES ARE CURRENTLY TAKING PLACE AS TO WHETHER IT IS POSSIBLE TO ACT MORALLY, IN OUR TECHNOLOGICAL SOCIETY, AND PROPOSALS HAVE BEEN MADE--QUITE SERIOUSLY--THAT SCIENCE SHOULD REPLACE TRADITIONAL ETHICS!

THE LAWS DISCLOSED BY SCIENCE MUST BE HEEDED BY THOSE WHO WISH TO EXPLOIT SCIENTIFIC DISCOVERIES. IN HIS TECHNOLOGICAL ACTIVITIES MAN IS BOUND BY THE LAWS OF SCIENCE. BUT IT DOES NOT FOLLOW THAT HE IS ALSO BOUND BY THE LAWS OF SCIENCE IN HIS PURELY HUMAN RELATIONS, AS WELL.

THROUGH TECHNOLOGY, MAN HAS BEEN RELIEVED OF MUCH BRUTAL, EXHAUSTING, PHYSICAL LABOR, AS WELL AS BORING ROUTINE WORK. WHY SHOULD THE EASE AND AFFLUENCE MADE POSSIBLE BY TECHNOLOGY AFFECT PRECEPTS THAT HAVE GUIDED WESTERN MAN FOR CENTURIES? I HAVE NOT YET FOUND OCCASION TO DISCARD A SINGLE PRINCIPLE THAT WAS ACCEPTED IN THE AMERICA OF MY YOUTH. WHY SHOULD ANYONE FEEL IN NEED OF A NEW ETHICAL CODE BECAUSE HE IS HEALTHIER OR BECAUSE HE HAS ACQUIRED BETTER TOOLS?

TOOLS ARE FOR UTILIZING THE EXTERNAL RESOURCES AT OUR DISPOSAL; PRINCIPLES ARE FOR MARSHALING OUR INNER, HUMAN RESOURCES. WITH TOOLS WE ALTER OUR PHYSICAL ENVIRONMENT; PRINCIPLES SERVE TO ORDER

OUR PERSONAL LIVES AND OUR RELATIONS WITH OTHERS. -THE TWO HAVE NOTHING TO DO WITH EACH OTHER.

IT DISTURBS ME TO BE TOLD THAT TECHNOLOGY "DEMANDS" AN ACTION THE SPEAKER FAVORS, OR THAT "YOU CAN'T STOP PROGRESS." IT TROUBLES ME THAT WE ARE PRESSURED BY TECHNOLOGY TO ALTER OUR LIVES, WITHOUT ATTEMPTING TO CONTROL IT--AS IF TECHNOLOGY WERE AN IRREPRESSIBLE FORCE OF NATURE TO WHICH WE MUST SUBMIT. NOT EVERYTHING HAILED AS PROGRESS CONTRIBUTES TO HAPPINESS; THE NEW IS NOT ALWAYS BETTER, NOR THE OLD ALWAYS OUTDATED.

MANY TEND TO CONFUSE TECHNOLOGY WITH SCIENCE. NOT ONLY IN POPULAR THINKING, BUT EVEN AMONG THE WELL-INFORMED, THE TWO ARE NOT ALWAYS CLEARLY DISTINGUISHED. IN CONSEQUENCE,-CHARACTERISTICS PERTAINING TO SCIENCE ARE ATTRIBUTED TO TECHNOLOGY.

SCIENCE HAS TO DO WITH DISCOVERING THE FACTS AND RELATIONSHIPS OF OBSERVABLE PHENOMENA IN NATURE, AND WITH ESTABLISHING THEORIES THAT SERVE TO ORGANIZE MASSES OF VERIFIED DATA CONCERNING THESE FACTS AND RELATIONSHIPS. BECAUSE OF THE CARE SCIENTISTS TAKE TO VERIFY THE FACTS SUPPORTING THEIR THEORIES, AND THEIR READINESS TO ALTER THEIR THEORIES WHEN NEW FACTS PROVE AN ESTABLISHED THEORY TO BE IMPERFECT, SCIENCE HAS GREAT AUTHORITY.

BUT TECHNOLOGY CANNOT CLAIM THE AUTHORITY OF SCIENCE. IT IS PROPERLY A SUBJECT OF DEBATE, NOT ONLY BY EXPERTS, BUT ALSO BY THE PUBLIC. IT HAS PROVED ANYTHING BUT INFALLIBLY BENEFICIAL. MUCH HARM HAS BEEN DONE TO MAN AND NATURE BECAUSE TECHNOLOGIES HAVE BEEN USED WITH NO THOUGHT FOR THE POSSIBLE CONSEQUENCES OF THEIR INTERACTION WITH NATURE. A CERTAIN RUTHLESSNESS HAS BEEN ENCOURAGED BY THE MISTAKEN BELIEF THAT THE DISREGARD OF HUMAN CONSIDERATIONS IS

AS NECESSARY IN TECHNOLOGY AS IT IS IN SCIENCE. THE ANALOGY IS FALSE.

THE METHODS OF SCIENCE REQUIRE RIGOROUS EXCLUSION OF THE HUMAN FACTOR. THESE METHODS WERE DEVELOPED TO SERVE THE NEEDS OF SCIENTISTS THE SEARCHER FOR TRUTH CANNOT PAY ATTENTION TO HIS OWN (OR TO OTHER PEOPLE'S) LIKES AND DISLIKES, OR TO POPULAR IDEAS OF THE FITNESS OF THINGS.

SCIENCE, BEING PURE THOUGHT, HARMS NO ONE; THEREFORE, IT NEED NOT BE HUMANISTIC. BUT TECHNOLOGY IS ACTION--OFTEN POTENTIALLY DANGEROUS ACTION. UNLESS IT IS MADE TO ADAPT ITSELF TO HUMAN INTERESTS, NEEDS, VALUES, AND PRINCIPLES, MUCH HARM WILL BE DONE. NEVER BEFORE, IN ALL HIS LONG LIFE ON EARTH, HAS MAN POSSESSED SUCH ENORMOUS POWER TO INJURE HIS FELLOWS, AND HIS SOCIETY, AS HAS BEEN PUT INTO HIS HANDS BY MODERN TECHNOLOGY.

THAT IS WHY IT IS IMPORTANT TO MAINTAIN A HUMANISTIC ATTITUDE TOWARD TECHNOLOGY; TO RECOGNIZE CLEARLY THAT, SINCE IT IS A PRODUCT OF HUMAN EFFORT, TECHNOLOGY CAN HAVE NO LEGITIMATE PURPOSE BUT TO SERVE MAN--MAN IN GENERAL, NOT MERELY SOME MEN; FUTURE GENERATIONS, NOT MERELY THOSE WHO CURRENTLY WISH TO GAIN ADVANTAGE FOR THEMSELVES; MAN IN THE TOTALITY OF HIS HUMANITY, ENCOMPASSING ALL HIS MANIFOLD INTERESTS AND NEEDS, NOT MERELY SOME ONE PARTICULAR CONCERN OF HIS. HUMANISTICALLY VIEWED, TECHNOLOGY IS NOT AN END IN ITSELF, BUT A MEANS TO AN END--THE END BEING DETERMINED BY MAN HIMSELF IN ACCORDANCE WITH THE LAWS OF HIS SOCIETY.

THE WORD "LAW" HAS COME TO HAVE TWO DISPARATE MEANINGS: LAW, AS COMMONLY UNDERSTOOD, REFERS TO THOSE RULES OF HUMAN CONDUCT PRESCRIBED AND ENFORCED BY SOCIETY; SCIENTISTS, WHO HAVE

APPROPRIATED THE TERM, USE IT TO DESCRIBE REGULARITIES EXHIBITED BY PHYSICAL PHENOMENA. IN THE TRANSITION, THE WORD HAS TAKEN ON A NEW MEANING.

LAW THAT GOVERNS HUMAN SOCIETY IS NOT THE RESULT OF SCIENTIFIC METHOD, BUT OF WISDOM AND EXPERIENCE. THIS LAW IS ALWAYS DEBATABLE AND CAN BE CHANGEDO WHAT THE SCIENTISTS CALL "LAW" IS REALLY IMMUTABLE FACTO IT IS LAW OPERATING IN A SPHERE WHERE MAN CAN EXERCISE NO INFLUENCE. MAN CANNOT ALTER THE LAWS OF THE COSMOS; HE CAN ONLY. DISCOVFR THEM. SCIENTIFIC LAW HAS RELEVANCE FOR MAN, ONLY BECAUSE IT MAKES THE UNIVERSE MORE COMPREHENSIBLE TO HIM AND, BY DISCLOSING HOW NATURE WORKS, ALLOWS HIM TO UTILIZE THE FORCES OF NATURE FOR HIS OWN PURPOSES.

WHEN WE MAKE USE OF THESE FORCES, WE MUST HEED THE LAWS OF SCIENCE WHICH DESCRIBE THEIR BEHAVIOR; THESE LAWS WE CANNOT BEND TO OUR WILL. BUT WE MUST LIKEWISE HEED THE MAN-MADE LAWS OF OUR SOCIETY, FOR TECHNOLOGY IS ACTION WHICH AFFECTS FELLOW HUMAN BEINGS. TECHNOLOGY, THEREFORE, IS SUBJECT TO THE LAW OF THE COSMOS AND TO THE LAW OF MAN.

EVER SINCE SCIENCE DISCOVERED THAT THE EARTH IS NOT THE CENTER OF THE COSMOS, AS HAD BEEN MAINTAINED BY THE HIGHEST HUMAN AUTHORITIES, WE HAVE BEEN LEARNING PAINFULLY THAT THE LAWS OF SCIENCE CANNOT BE OVERTURNED BY HUMAN FIAT. TODAY, ACCEPTANCE OF DULY AUTHENTICATED SCIENTIFIC THEORIES OR LAWS IS COMMON PRACTICE IN ENLIGHTENED COUNTRIES.

WE HAVE BEEN EXCESSIVELY TOLERANT TOWARD THOSE WHO CLAIM THE RIGHT TO USE TECHNOLOGY AS THEY SEE FIT, AND WHO TREAT EVERY ATTEMPT

BY SOCIETY TO REGULATE SUCH USE IN THE PUBLIC INTEREST AS IF IT WERE A MODERN REPETITION OF THE PERSECUTION OF GALILEO!

ASSUREDLY, WE HAVE THE RIGHT TO USE THE LAW AND GOVERNMENT TO PROTECT OURSELVES AGAINST TECHNOLOGICAL INJURY. WHEN DIFFERING WITH THOSE WHO WOULD RESTRAIN THE USE OF TECHNOLOGY, IT IS COMMON PRACTICE TO ARGUE AS IF AT ISSUE WERE ACCEPTANCE OF A LAW OF SCIENCE. YET, WHAT IS BEING DISCUSSED IS NOT SCIENCE, BUT THE ADVISABILITY OR LEGALITY OF THE TECHNOLOGICAL EXPLOITATION OF SCIENCE. WE WOULD NOT BE DECEIVED BY SUCH ARGUMENTS IF WE CLEARLY UNDERSTOOD THE FUNDAMENTAL DIFFERENCE BETWEEN SCIENCE--WHICH IS PURE KNOWLEDGE--AND TECHNOLOGY--WHICH IS ACTION BASED ON KNOWLEDGE.

WE SHOULD CULTIVATE AN ATTITUDE OF SKEPTICISM WHENEVER THE WORD "SCIENCE" IS USED. IS IT "SCIENCE" THAT IS BEING DISCUSSED, OR IS IT "TECHNOLOGY"? IF IT IS TECHNOLOGY, THE QUESTION ARISES WHETHER THE PROPOSED ACTION IS LEGALLY PERMISSIBLE, AND SOCIALLY DESIRABLE. TECHNOLOGY MUST CONFORM TO THAT MOST BASIC OF ALL LEGAL MAXIMS, THE "MUTUALITY OF LIBERTY": THE PRINCIPLE THAT ONE MAN'S LIBERTY OF ACTION ENDS WHERE IT WOULD INJURE ANOTHER'S

HUMANISTICALLY VIEWED, TECHNOLOGY CAN HAVEN LEGITIMACY UNLESS IT INFLICTS NO HARM. THE PREREQUISITE FOR USERS OF TECHNOLOGY IS--OR OUGHT TO BE--THAT THEY COMPREHEND AND RESPECT THE LAWS OF SCIENCE APPLICABLE TO THEIR PARTICULAR TECHNOLOGY; THAT THEY EXERCISE CARE IN ASSESSING THE PROBABLE CONSEQUENCES OF THIS TECHNOLOGY; AND, SHOULD IT BE POTENTIUHARMFUL, THAT THEY ABSTAIN FROM USING THE TECHNOLOGY UNTIL THEY HAVE FOUND WAYS TO RENDER IT SAFE.

WHETHER A PARTICULAR TECHNOLOGY HAS HARMFUL POTENTIALITIES OUGHT NOT TO BE DECIDED UNILATERALLY BY THOSE WHO WISH TO USE IT.

DESTRUCTIVE TECHNOLOGIES ARE OFTEN HIGHLY PROFITABLE FOR THOSE PROMOTING THEM. MOREOVER, THOSE WHO PROMOTE TECHNOLOGY ARE NEARLY ALWAYS PRACTICAL: MEN MORE KNOWLEDGEABLE ABOUT EFFICW IN USING A TECHNOLOGY THAN ABOUT THE LEGAL AND SCIENTIFTC IMPLICATIONS OF ITS USE.

THE PRACTICAL APPROACH TO A NEW SCIENTIFIC DISCOVERY, AND ITS USE THROUGH TECHNOLOGY, IS USUALLY SHORT-RANGE AND PRIVATE, CONCERNED ONLY WITH WAYS TO PUT THE DISCOVERY TO USE IN THE MOST ECONOMICAL,AND EFFICIENT MANNER, LITTLE THOUGHT BEING GIVEN TO ITS ULTIMATE CONSEQUENCES. THE SCHOLARLY APPROACH IS LONG-RANGE AND PUBLIC; IT LOOKS TO THE EFFECTS WHICH A NEW TECHNOLOGY MAY HAVE ON PEOPLE IN GENERAL, ON THE NATION, ON THE WORLD; ON PRESENT AND FUTURE GENERATIONS.

I CAN BEST ILLUSTRATE WHAT I WANT TO BRING OUT BY A SIMPLE EXAMPLE. COMMERCIAL DEEP-SEA FISHING CAN BE DONE SO EFFICIENTLY WITH MODERN TECHNIQUES THAT A FEW ENTERPRISES COULD RAPIDLY SWEEP THE OCEANS FREE OF COMMERCIAL FISH. YET, THIS IS WHAT THE FISHERMEN OF ALL NATIONALITIES WISH TO DO. AS PRACTICAL MEN, THEY ARE INTERESTED ONLY IN USING TECHNOLOGY TO INCREASE THEIR CATCH, PRESERVE IT, AND GET IT TO MARKET AS SPEEDILY AS POSSIBLE. IN PURSUING THIS SHORT-RANGE, PRIVATE OBJECTIVE, THEY HAVE BEEN INGENIOUS. FIGURATIVELY SPEAKING, THE WORLD'S MARINE SCHOLARS HAVE STOOD BY, WRINGING THEIR HANDS AT THE FISHERMEN'S "PRACTICAL" FOLLY. TO THE SCHOLARS IT HAS BEEN INCOMPREHENSIBLE THAT RATIONAL HUMAN BEINGS SHOULD FAIL TO SEE THAT, IN THE END, MORE CAN BE TAKEN FROM THE SEA IF FISHING CONFORMS TO SENSIBLE CONSERVATION MEASURES, WHICH PERMIT THE SPECIES TO REPRODUCE ITSELF.

WE WITNESS AT THE MOMENT THE END OF ONE OF THE SADDEST CASES OF MISUSE OF TECHNOLOGY BY GREEDY FISHING INTERESTS. UNLESS THESE INTERESTS ARE CURBED BY TRULY EFFECTIVE INTERNATIONAL ACTION, THE GREAT WHALES--THE BLUE, THE FINBACK, THE SPERM--WILL SOON DISAPPEAR, VICTIMS OF MAN'S "PRACTICAL" FOLLY.

HUNTING MANY SPECIES OF WHALES, INCLUDING THE BLUE WHALE, HAS NOW BEEN PROHIBITED; BUT NOT SO WITH MANY OTHER SPECIES, SUCH AS THE FINBACK WHALE. THE CONSERVATION MEMBERS OF THE WHALING COMMISSION ARE WILLING TO BAN THE CATCHING AND KILLING OF ALL WHALES--BUT ALL MEMBERS OF THE COMMISSION WILL NOT AGREE. THE CONSERVATION MEMBERS HOPE TO BRING ABOUT A COMMERCIAL MORATORIUM ON THE KILLING OF WHALES IN THE NEAR FUTURE. HOWEVER, DESPITE LONG EFFORTS TO REGULATE WHALING, THE PROBLEM STILL EXISTS.

PRACTICAL CONSIDERATIONS ASIDE, IS ANYONE JUSTIFIED IN USING TECHNOLOGY TO EXTERMINATE A SPECIES THAT HAS EXISTED ON THIS EARTH FOR EONS--THE LARGEST ANIMAL THE WORLD HAS EVER SEEN? ARE WE CERTAIN THAT OUR DESCENDANTS MAY NOT AT SOME FUTURE TIME HAVE NEED OF THESE MAMMALS? R. A. PINDLETON, IN HIS BOOK <u>THE LIMITS OF MANKIND,</u> REMARKS THAT NOBODY KNOWS WHAT THE BIOLOGICAL CONSEQUENCES ARE LIKELY TO BE OF THE WHALES' EXTERMINATION. "BUT," HE SAYS, "IF NEARLY A MILLION OF THESE HUGE ANIMALS, WITH THEIR ENORMOUS APPETITES, CAN BE REMOVED IN A SINGLE GENERATION FROM THE BALANCE OF MARINE LIFE WITHOUT CAUSING VIOLENT REPERCUSSIONS, ALL OUR PREVIOUS EXPERIENCE OF THIS SUBJECT HAS GIVEN US THE WRONG ANSWERS."

IRRETRIEVABLE DAMAGE HAS BEEN DONE BY THOSE WHO USE TECHNOLOGY WITHOUT GIVING THOUGHT TO ITS EFFECT ON OUR ENVIRONMENT. WASTE PRODUCTS, CARELESSLY EMITTED, CREATE A MASSIVE PROBLEM OF SOIL,

WATER, AND AIR POLLUTION--WE MAY BE DAMAGING THE ATMOSPHERE PERMANENTLY BY CHANGING ITS CHEMICAL COMPOSITION. WHOLESALE SLAUGHTER OF WILD ANIMALS UPSETS THE ECOLOGY WITH CONSEQUENCES WE CANNOT EVEN FATHOM AS YET.

EXPERIENCE SHOWS THAT BY ITSELF, THE LEGAL MAXIM OF THE "MUTUALITY OF LIBERTY" WILL NOT PREVENT PREMATURE COMMITMENT TO TECHNOLOGIES THAT MAY LATER PROVE HARMFUL. THE MAXIM MUST BE IMPLEMENTED BY PREVENTIVE PUBLIC ACTION--ACTION OF THE KIND THAT HAS LONG BEEN OPERATIVE IN THE FIELD OF PUBLIC HEALTH. THERE IS NEED FOR LAWS REQUIRING THAT BEFORE A PARTICULAR TECHNOLOGY MAY BE USED, RELIABLE TESTS MUST HAVE BEEN MADE TO PROVE IT WILL BE USEFUL AND SAFE.

WARNINGS OF SCIENTISTS HAVE BEEN REJECTED AS "UNPROVEN" AND "EXAGGERATED." LATER, WHEN THESE WARNINGS PROVE TO HAVE BEEN ENTIRELY CORRECT, THE ARGUMENT SHIFTS FROM WHETHER A TECHNOLOGY IS HARMFUL, TO AN ATTACK ON ANY KIND OF PROTECTIVE LEGISLATION. LEGISLATION WOULD VIOLATE BASIC LIBERTIES, IT IS CLAIMED; IT WOULD ESTABLISH GOVERNMENT TYRANNY AND SUBVERT FREE DEMOCRATIC INSTITUTIONS.

THESE DELAYING TACTICS ARE HIGHLY EFFECTIVE. IT TAKES FIRM COMMITMENT TO A HUMANISTIC TECHNOLOGY TO PUSH THROUGH NEEDED LEGISLATION. PUBLIC OPINION AND THE LAW HAVE NONHERE FULLY CAUGHT UP WITH THOSE WHO MISUSE TECHNOLOGY. OFTEN THEY ESCAPE WITH IMPUNITY, NO MATTER HOW GRAVELY THEY INJURE MAN OR THEIR SOCIETY.

LET ME GIVE YOU ONE MORE EXAMPLE OF THE HARM DONE BY TECHNOLOGICAL INTERFERENCE. TODAY WE HAVE NEW TECHNOLOGIES FOR THE DESTRUCTION OF INSECT PESTS AND WEEDS. THE USE OF THESE

TECHNOLOGIES IS PROFITABLE FOR THE MANUFACTURERS OF PESTICIDES AND WEED-KILLERS; IT IS HELPFUL TO FARMERS, WHO ARE ABLE TO GET BETTER CROPS, REDUCE HUMAN LABOR, AND PRODUCE A GREATER PROFIT; IT BENEFITS CONSUMERS. HERE IS A CLASSIC CASE OF WHAT TECHNOLOGY CAN DO FOR us. UNFORTUNATELY, WE HAVE LEFT OUT OF CONSIDERATION THE BALANCE OF NATURE. IF USED IMPROPERLY, THESE PESTICIDES AND WEED-KILLERS POISON SOIL, CROPS, BIRDS, ANIMALS, FISH, AND--EVENTUALLY--MAN.

WHEN THE BALANCE OF NATURE IS UPSET, EVERYTHING IN NATURE IS THREATENED, INCLUDING MAN HIMSELF. UNLESS HE HIMSELF SETS LIMITS TO HIS DESTRUCTIVE INSTINCT, HE WILL ULTIMATELY EXTERMINATE ALL WILD-LIFE. HE WILL THEN BE LEFT ALONE ON EARTH WITH HIS DOMESTICATED ANIMALS, AND WITH SWARMS OF INSECTS AND GERMS; ALONE IN A WORLD HE HAS FASHIONED IN THE IMAGE OF HIS TECHNOLOGY.

TO MAKE TECHNOLOGY SAFE, WE MUST HAVE PROTECTIVE LAWS. BUT MORE IS NEEDED. LAW AND PUBLIC OPINION ALWAYS LAG BEHIND THE SWIFT DEVELOPMENT OF NEW TECHNOLOGIES. THEREFORE, WE ALSO NEED MORE RESPONSIBLE THINKING AMONG THOSE WHO MANAGE TECHNOLOGIES. THIS CAN BEST BE BROUGHT ABOUT BY PROFESSIONALIZING THE DECISION-MAKING PROCESS IN TECHNOLOGY. IN THE HANDS OF PROFESSIONALS, TECHNOLOGY IS MANAGED WITH GREATER CONCERN FOR HUMAN WELFARE, THAN WHEN IT IS CONTROLLED, AS AT PRESENT, BY NON-PROFESSIONALS.

SPECIAL KNOWLEDGE AND SKILL OUGHT TO BE USED HUMANISTICALLY, INSTEAD OF FOR PERSONAL AGGRANDIZEMENT OR POWER. YET THIS PRECEPT IS RARELY FOLLOWED OUTSIDE MEDICINE AND A FEW OTHER OF THE SO-CALLED LEARNED, OR LIBERAL PROFESSIONS. MOST HUMAN AFFAIRS ARE CONDUCTED. ON THE OLD ROMAN MAXIM, <u>CAVEAT EMPTOR.</u>

I HAVE LONG BELIEVED THAT WE SHOULD COME APPRECIABLY CLOSER TO A HUMANISTIC TECHNOLOGY IF ENGINEERING WERE PRACTICED AS A HUMANISTIC PROFESSION AND IF ENGINEERS WERE ACCORDED THE PROFESSIONAL INDEPENDENCE GRANTED MEMBERS OF LIBERAL PROFESSIONS. ENGINEERS WOULD THEN FIND IT POSSIBLE TO ACT WITH THE SAME SENSE OF PROFESSIONAL RESPONSIBILITY AND SERVICE TO HUMANITY THAT IS CHARACTERISTIC OF GOOD PHYSICIANS.

PROFESSIONAL INDEPENDENCE IS NOT A SPECIAL PRIVILEGE, BUT RATHER AN INNER NECESSITY FOR THE TRUE PROFESSIONAL MAN; IT IS ALSO A SAFEGUARD FOR HIS EMPLOYER AND FOR THE PUBLIC. IT IS WHAT CHIEFLY SETS HIM APART FROM THE SKILLED TECHNICIAN.

THIS INDEPENDENCE OF PROFESSIONAL JUDGMENT HAS NOT YET BEEN ACCORDED THE ENGINEER. HE STILL HAS TO WIN IT FOR HIMSELF. IT CAN HAPPEN THAT AN EXPERIENCED ENGINEER'S PROFESSIONAL JUDGMENT WILL BE OVERRULED BY A LAY SUPERIOR, WHILE NO ONE WOULD THINK OF DICTATING TO A PHYSICIAN. YET THE UNIVERSITY-TRAINED ENGINEER IS AS COMPETENT A PROFESSIONAL IN HIS FIELD AS IS THE PHYSICIAN. THE DIFFERENCE LIES IN THE DETERMINATION OF THE MEDICAL PROFESSION TO RESIST LAY INTERFERENCE, AND IN ITS SUCCESS IN WINNING THIS POINT, WHILE THE ENGINEERING PROFESSION HAS SHOWN LITTLE DETERMINATION TO RESIST AND SO HAS HAD LITTLE SUCCESS.

MY WORK IS IN ONE OF THE NEW TECHNOLOGIES; ONE THAT IS DANGEROUS UNLESS PROPERLY HANDLED. I HAVE BEEN FACED WITH THE DIFFICULTY OF CONVINCING ADMINISTRATORS ABOVE ME THAT IT IS NOT SAFE FOR THEM TO OVERRULE THEIR TECHNICAL EXPERTS. HERE IS A CASE IN POINT:

A SUPERIOR ONCE ASKED ME TO REDUCE RADIATION SHIELDING IN OUR NUCLEAR SUBMARINES. HE SAID THE ADVANTAGE OF GETTING A LIGHTER-WEIGHT REACTOR PLANT WAS WORTH RISKING THE HEALTH OF PERSONNEL. IT WAS NOT POSSIBLE TO MAKE HIM SEE THAT I COULD NOT AND WOULD NOT ACCEPT SUCH A CONCEPT. WHERE RADIATION IS INVOLVED, WE ARE DEALING NOT JUST WITH THE LIVES OF PRESENT-DAY INDIVIDUALS, BUT WITH THE GENETIC FUTURE OF MANKIND. HIS ATTITUDE WAS THAT WE DID NOT KNOW MUCH ABOUT EVOLUTION; AND IF WE RAISED RADIATION EXPOSURE, WE MIGHT FIND THE RESULTING MUTATIONS TO BE BENEFICIAL--IN OTHER WORDS, THAT MANKIND MIGHT "LEARN TO LIVE WITH RADIATION." REGARDLESS OF HIS REQUEST, I DID NOT REDUCE THE THICKNESS OF THE SHIELDING.

HOW WE USE TECHNOLOGY AFFECTS PROFOUNDLY THE SHAPE OF OUR SOCIETY. WHAT USE HAVE WE MADE OF IT? WE HAVE MULTIPLIED INORDINATELY (IN 70 YEARS, WE WILL EVEN OUT AT 350 MILLION PEOPLE), WASTED IRREPLACEABLE FUELS AND MINERALS, AND PERPETUATED INCALCULABLE AND IRREVERSIBLE ECOLOGICAL HARM. I CAN FIND NO EVIDENCE THAT MAN CONTRIBUTES <u>ANYTHING</u> TO THE BALANCE OF NATURE. ON THE STRENGTH OF HIS LIMITED KNOWLEDGE OF NATURE, HE HAS SET HIMSELF ABOVE NATURE; HE HAS PRESUMED TO CHANGE THE NATURAL ENVIRONMENT FOR ALL THE LIVING CREATURES OF THIS EARTH. DO WE, WHO ARE TRANSIENTS AND NOT OVERLY WISE, REALLY BELIEVE WE HAVE THE RIGHT TO UPSET THE ORDER OF NATURE, AN ORDER ESTABLISHED BY A POWER HIGHER THAN MAN?

HOW, IN FUTURE, TO MAKE WISER USE OF TECHNOLOGY IS PERHAPS THE PARAMOUNT PUBLIC ISSUE FACING ALL INDUSTRIAL DEMOCRACIES. THIS PROBLEM IS DIFFICULT ENOUGH IN ITSELF, BUT MADE STILL MORE SO BY THOSE WHO WISH TO CONTINUE USING HARMFUL TECHNOLOGIES.

GOVERNMENT HAS AS MUCH A DUTY TO PROTECT THE LAND, THE AIR, THE WATER, THE NATURAL ENVIRONMENT OF MAN AGAINST DAMAGE, AS IT HAS TO PROTECT THE COUNTRY AGAINST ENEMIES, AND THE INDIVIDUAL AGAINST CRIMINALS; CONVERSELY, EVERY CITIZEN IS DUTY BOUND TO MAKE AN EFFORT TO UNDERSTAND HOW TECHNOLOGY OPERATES AND WHAT ITS POSSIBILITIES AND LIMITATIONS ARE. ALL THIS IS NECESSARY, IF TECHNOLOGY IS TO BE ASSIGNED ITS PROPER PLACE IN HUMAN AFFAIRS, IF IT IS TO BE MADE HUMANISTIC.

A FREE SOCIETY CENTERS ON MAN. IT GIVES PARAMOUNT CONSIDERATION TO HUMAN RIGHTS, INTERESTS, AND NEEDS. BUT ONCE ORDINARY CITIZENS COME TO FEEL THAT PUBLIC ISSUES ARE BEYOND THEIR COMPREHENSION, A PATTERN OF LIFE MAY DEVELOP IN WHICH TECHNOLOGY, NOT MAN, WOULD BECOME CENTRAL TO THE PURPOSE OF SOCIETY. IF WE WERE TO PERMIT THIS TO HAPPEN, THE HUMAN LIBERTIES, FOR WHICH MANKIND HAS FOUGHT FOR SO LONG AT SO GREAT A COST OF EFFORT AND SACRIFICE, WILL BE EXTINGUISHED.

PRODUCTIVITY REDISCOVERED

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Mr. Brasher has a B.S. degree from Millsaps College. After graduation, he joined the E.I. duPont de Nemour, Inc., at the Savannah River Plant. After 5 years with duPont Mr. Brasher joined Ingalls Shipbuilding and served in various positions, including Chief Nuclear Scientist and Director, Radiation Control in the company's nuclear program.

In 1980, after 19 years at IngalIs, Mr. Brasher accepted a position with GPU Nuclear, the company operating Three Mile Island Nuclear Generating Station. At GPU Nuclear Mr. Brasher was Director, Radiological Controls, and in that capacity had the responsibility for radiological controls during the recovery activities.

In 1982 Mr. Brasher returned to Ingalls Shipbuilding as Director, Productivity and Operational Evaluation. In this position he reports to the Division president and is responsible for the division activities in productivity and in performing operational evaluations of the several directorates.

ABSTRACT

In world class competition, productivity or lack thereof can mean the difference between 5% unemployment and 15+% unemployment. Contrary to popular opinion the higher unemployment will result form lack of such productivity improvement innovations as automation. Productivity improvement, properly prioritized, is easy yet difficult. This talk covers both sides of the issue and offers program suggestions applicable to any endeavor.

PRODUCTIVITY REDISCOVERED

Productivity is a "hot" issue today. Pick up almost any national industry or technical magazine and there is one or more productivity articles inside. The topic may be cost cutting, automation, quality circles, statistical control or robotics; but in essence all relate to productivity.

Between '1945 and 1965 productivity in this country increased at an average rat-e OF 3.2 percent per year. For the ye'ars 1973 through 1979 the average U. S. productivity growth was 0.9 percent. For that same period the average productivity growth for West Germany was 5 percent and for France was 4.8 percent. During the years 1979 and 1980 there was no productivity growth in the United States.

There is a cause and an effect relationship between these data and other economic and industrial data. Consider this: (VU GRAPH). During the period 1972 to 1983 United States unemployment increased from 5.6 percent to 9.8 percent while (VU GRAPH) in the years 1973 to 1982 foreign car imports increased from 1.8 million to 2.6 million. U. S. steel shipments for the period 1973 to 1982 decreased by one-half to about 63 thousand tons. For 1982 alone imported steel equaled nearly one-third of our domestic shipments. From a single Far East country we import 20 - 25 percent of our automobiles, 90 percent of our motorcycles, over 50 percent of our watches and recording equipment and 20 percent of our machine tools. As if that were not bad enough (VU GRAPH), take a look at what has happened in the foreign car market. Dollar volume has

continued to grow at a steady rate from 12 billion in 1975 to 30 billion in 1981, even with leveling off sales in recent years. Like it or not, we are in world competition and there is only one acceptable response -- gear up for world class competition!

R. W. Barrett, President of the Society of Manufacturing Engineers, in addressing the current situation stated, "The only way out of this dilemmais through more effective utilization of the basics, which is to say through an increase in productivity". As one can observe from past and current experience, productivity cannot, even be permitted to level off; it must continue to increase or else the economy ceases to grow.

A recent report by the Committee for Economic Development states, "It is important for all who take action to understand that half-hearted, piecemeal measures will simply not be effective in raising u. s. productivity to a level where American products and workers are competitive".

This sounds like 'Productivity Discovered". Why the "Productivity Rediscovered"? Some years ago a national magazine carried a short story concerning Henry Ford and one of his T-Model parts suppliers. The supplier was delighted to receive the parts order, but was greatly annoyed that the order came specifying precisely how the parts were to be crated for shipment. He was required to use a specific type and thickness plywood, a certain size on each side and oddly had to have rectangular slots at very precise locations on one side.

The shipping crates had to be bolted together at specified points with a specific size and type bolt. None of this made any sense to the supplier. What the supplier did not know, of course, was that upon arrival at the Ford plant the crates would be carefully disassembled after the ordered parts were removed and the crate sides became the exact fit floorboards for Mr. Ford's cars, even to the use of the shipping bolts to hold them down. .That is productivity. Henry Ford had it and in many areas of this country we still do. Oh, yes, the rectangular slots -- they were cutouts for the brake and the clutch.

A recent ship construction report identified a number of recommendations intended to improve productivity in United States shipyards. Essentially, all of the recommendations called for more studies, evaluations or investigations. Some or all of these studies may be worthwhile; however, I am convinced that there is available a host of data that indicate more action and less studies are in order. (VU GRAPH). We need a bias for action in American shipbuilding and in American industry. (VU GRAPH).

It takes time to modernize, to automate, to implement new technology or to install new management concepts. Assuming capital were available and management were receptive, to implement the most modern of systems and technology in an existing shipyard, if done orderly, the process could take over 5 years. If capital is limited, and it is, and management is not totally receptive, and it may not be, one is at liberty to fill in his own timetable of how long it will take the shipbuilders of America to even fully utilize. tools available in 1983. Is 5 years good enough? While that process is

urgently needed and I urge it as a national priority, it is not adequate. Even today one of our chief industrial competitors in the Far East is developing a 5-year plan to dramatically reduce ship construction costs there which, as you know, are already significantly below ours.

Many of, the productivity concepts so successfully applied by our foreign competition were imported from the United States. In reference to that, a recent productivity article stated, "Imitators make poor innovators and innovation has been and still is America's most potent competitive weapon". We must use that innovation weapon to leap frog the competition or be satisfied to sell only to closed and limited domestic markets or close the doors.

I see six steps or phases of a productivity program. These are (VU GRAPH): (1) Need, (2) Charter, (3) Plan, (4) Analysis, (5) Action and (6) Validation. There are many personal preference paths one can take in implementing a productivity improvement program. However, the relative success of the effort depends on some key 'elements.

Once the need (or necessity) is recognized the productivity effort must be commissioned by' top management preferably by the company president or CEO. This commission must clearly indicate the

source of the authority, the associated policy statement and that the effort is permanent. The policy should define productivity or productivity improvement such that all employees will comprehend its scope. (VU GRAPH). I have defined productivity improvement as indicated on the vu graph. Productivity does not deal only with stamping out gadgets at a rapid rate; the gadget must be marketab.le. Being marketable invokes technology, price, quality, safety, and a host of other factors. Productivity means being in business tomorrow.

The "targets of opportunity" approach to productivity, even if done poorly, is usually better than no program at all; however, it can never compete with a fully developed plan that takes into account the individual processes and then coordinates the individual processes with the total manufacturing effort. A comprehensive plan helps prevent the type errors that result from one process being upgraded to a very high output while the next stage prevents taking advantage of that capacity. Many industries can relate painful and costly experiences with an unorganized approach.

The first attribute of a plan is that it involve all company organizations and all employees. The plan should start with the positive attitude (VU GRAPH) that any endeavor can be done better, cheaper and easier. It must be consistently and uniformly applied. The plan should recognize that there is no magic formula which will yield a dramatic increase in productivity and it is the exception where massive productivity improvements are the result of the "big bang". More likely there will be incremental increases which

provide a steady growth in productivity as a result of a long term, consistently applied program.

It is somewhat risky to state unequivocably which phase is the most important; however, the analysis phase sets the stage for the action phase, therefore it becomes the pivot point. It is at this stage that one must consider how the improvements in productivity are to be effected. Ts it new equipment, reorganization, research and development of new processes, putting in a quality circle program that will do the trick? Actually, all and others may be useful; however, there is a universal approach which is applicable to any organization and any organizational division in performing an analysIS.Ts. (VU GRAPH).

First, analyze the management (including manufacturing) systems such as flow and organization of work. Not only does this area offer by far the greatest number of opportunities to improve productivity, but also many improvements in this area can be made with little or no capital investment.

Automated factories, computer aided design and manufacture, robotics and electronic mail systems all offer substantive productivity increases and are urgently needed.

However, due to the cost of capital many organizations can only make modest investments in new technology equipment. Not only is capital difficult to obtain to purchase new and modern equipment, but this step is also placed not second, but in series after analysis of management systems since it does not make good logic

to buy and install modern equipment for an outmoded and inefficient management or manufacturing system. Nevertheless, acquisition of state-of-the-art equipment and technology is equally as important to successful world class competition as updating management systems.

The third leg of this triangle is development of new technology. An applied research and development program is essential to further advances in the state-of-the-art. We have already seen that a continuing improvement in efficiency and productivity is going to be a part of everyday life for the successful organization of the future. Prioritized application of these three elements will help make the operational evaluation phase more meaningful and more implementable.

Analysis of current operations will detect some sensitive spots if it is an effective one. Since you have already written the plan to actively involve all organizations in the productivity improvement area, one of the chief concerns by some managers of outsiders infringing on their turf is addressed by making the analysis at least partially an'internal review. A second point that is frequently voiced when someone suggests a new piece of automated equipment is that automation takes jobs away from people. This is a myth. (VU GRAPH). Much of this country's current economic plight is not due to automation, but a failure to automate. Automation creates jobs and saves other jobs. That statement may not mean full

employment; but it does mean that if the country does not automate unemployment will be higher, perhaps much higher -- not lower. For those of you who have not received today's bit of trivia, punched cards were first used to provided an automated control system for weaving looms in 1728.

In the planning stage or the analysis stage someone is going to bring up quality of work life and quality circles. Much has been said and written about quality circles, participative management and similar efforts. The essence of these efforts is that an employee (1) has .an opportunity to voice his opinions on how his (and other) work is done and how work should or should not be done, (2) he is heard by management or representatives of management and (3) where appropriate management action is taken on the employee's observations.

(VU GRAPH). It is not necessary that one have a formal or structured communications program; however, it is critical to the success of a company that company employees who happened to be engaged in management activities listen to and be responsive to contributions of company employees who happen to be engaged in non-management functions. How does one do that outside a structured program? Simply by talking with people and asking the appropriate

questions. You will find that most people really appreciate management's help in getting the operation squared away. It has been shown conclusively that the overwhelming majority of people not only want to be a part of a winning team, they also consider themselves winners. If you want to raise morale as well as performance', tap this powerful resource.

A final point on 'operational evaluations. Recognize up front that few organizations can man permanent full-time analysis teams and, therefore, some decisions on prioritizing are necessary. Obviously, the more significant paybacks and/or easier-to-execute areas must receive first attention. After or even during the analysis stage, there is also a necessity to prioritize implementation.

Having recognized a need, commissioned a program, developed a plan and performed the analysis, the easy part is complete. Typically, the most difficult stage is implementation and there are a number of reasons for that. First, implementation generally takes more resources, both financial and human, than any of the earlier stages and in addition in almost every organization one will find some resistance to changing whatever system is now in place. Dealing with these three issues, dollar cost, human resource cost and resistance to change makes this phase of the total program the most difficult. In reference to many people's resistance to change, I am reminded of a statement in Peters and Waterman's book, "In Search of Excellence". In discussing the issue they

say it is inherently easier to argue why something should not be done than to identify reasons why it should be done. James Lardner, Vice President of Manufacturing, Deere & Co., some months ago stated, "In many American companies too few senior managers are interested in or wish to become involved with new technologies. By default, sponsorship of new technology becomes a bottoms-up effort driven by young, enthusiastic, impatient middle level technicians and managers who struggle to push acceptance up through an unsympathetic, uncomprehending, conservative bureaucracy."

The 6th Step in the program, validation,is an enigma to many. In the literature, corporate and government circles one will find extensive dissertations on the problem of how to measure productivity. The answer to that question is quite simple and there is a new law that has universal application. The law is stated as:

> Productivity is inversely proporational to the square of the total number of meetings, written articles, seminars, speeches, etc., on productivity. (VU GRAPH).

Now that may be somewhat exaggerated; however, there is an element of truth in it for as productivity is increased in the United States, and it will be, the number of productivity papers, etc., will decrease simply because there is less effort required to sustain a program than it is to get one moving again. (VU GRAPH).

The cost of implementing a productivity improvement initiative, particularly should there be capital expenditures involved, is

historically available, to some degree of accuracy, because such efforts have to be sold to management.

measurement of an' incremental change (hopefully an increase) in productivity after implementation of a change

may be readily quantifiable such as in the case of a headcount decrease however the synergestic effects of improved performance by one organization on another organization are very difficult to quantify. How does one measure the effect of beating a drawing release schedule or a "no wait" material system or an error-free job instruction? The need to know, within reason, performance and performance changes is important and must be considered and carefully evaluated. However, when one is tempted to agonize over the precise measurement of productivity he should remember an oft overlooked fact. (VU GRAPH). Productivity is relative. What may have been excellent yesterday may drive one out of business today. In some situations attempting to precisely measure all of the elements of an incremental change in productivity could consume the savings of the change. No organization should permit itself to get bogged down in the quagmire of absolute measurements of productivity to the detriment of achieving productivity.

Before closing, permit me to mention two other topics briefly: Quality and Education. In many respects quality and productivity are synonymous. (VU GRAPH). Quality can be achieved in the absence of productivity; however, productivity cannot be achieved in the absence of quality. Quality knows no organizational boundaries. Quality Control belongs in the hands of the performer and it matters not whether the individual is welding, designing a new product, writing a procedure or training a new employee. In reference to quality work, Lawrence Sullivan, Ford's manager of reliability and warranty, stated that if present cost cutting efforts continue Ford will be able to cut as much as $1,000 off the current $2,200 manufacturing cost differential between the U. S. and Japanese cars.

It is not my intent to become involved in a finger-pointing contest on the subject of education, because if the truth were really faced we would probably see the guilty party in the mirror every morning as we shaved. There are some sobering data which may be of interest, however:

About half.of the engineering doctorates graduated at U. S. universities are awarded to foreign students.

All of our universities produce only about 200 computer science Ph.D's each year.

In 1980 only 25% of the U. S. high school graduates completed enough mathematics and science to enter engineering programs in college.

Two-thirds of our high schools require one year of math or science and at least half of all high school seniors graduated without a single year of chemistry or physics. Since 1971 there has been a 77% decrease in the number. of qualified math teachers and a 65% decrease in the number of qualified science teachers in our secondary schools. Half of the newly employed secondary school science and math teachers are unqualified to teach the subjects but were hired on a best available basis because qualified teachers could not be found.

Now is not necessary that the consequences of these data be iterated, rather the effort should be directed to remedial action. There is more to be done ' than I would even attempt to list; however, there is one action that I consider. a keystone (VU GRAPH). A consistent, serious investment in education and research on the part of every company according to its use of human resources and technology is vital to achieving significant advances in education and research and to the success and continued success of any company in world class competition.

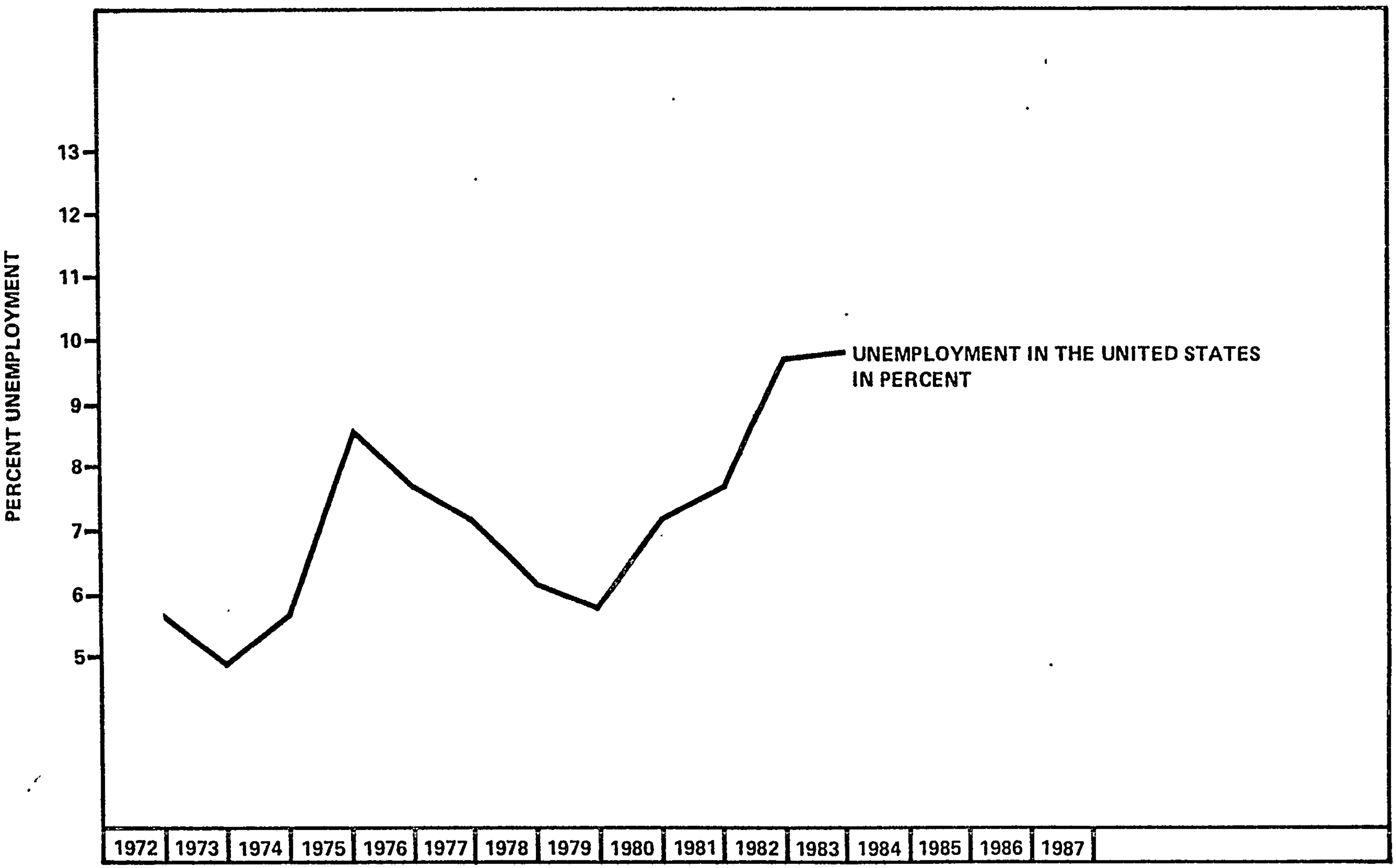
You have heard national economic and industrial figures, an approach to improving productivity in any organization, including

governmental, a few comments on quality and some gloomy data on current education. In my opinion all of these data are related, some perhaps indirectly, but related nevertheless. Should you leave this symposium with nothing else, please do not leave it without a bias for action on your part and the part of your organization.

MV-9890

PRODUCTIVITY REDISCOVERED

INGALLS Shipbuilding
Litton



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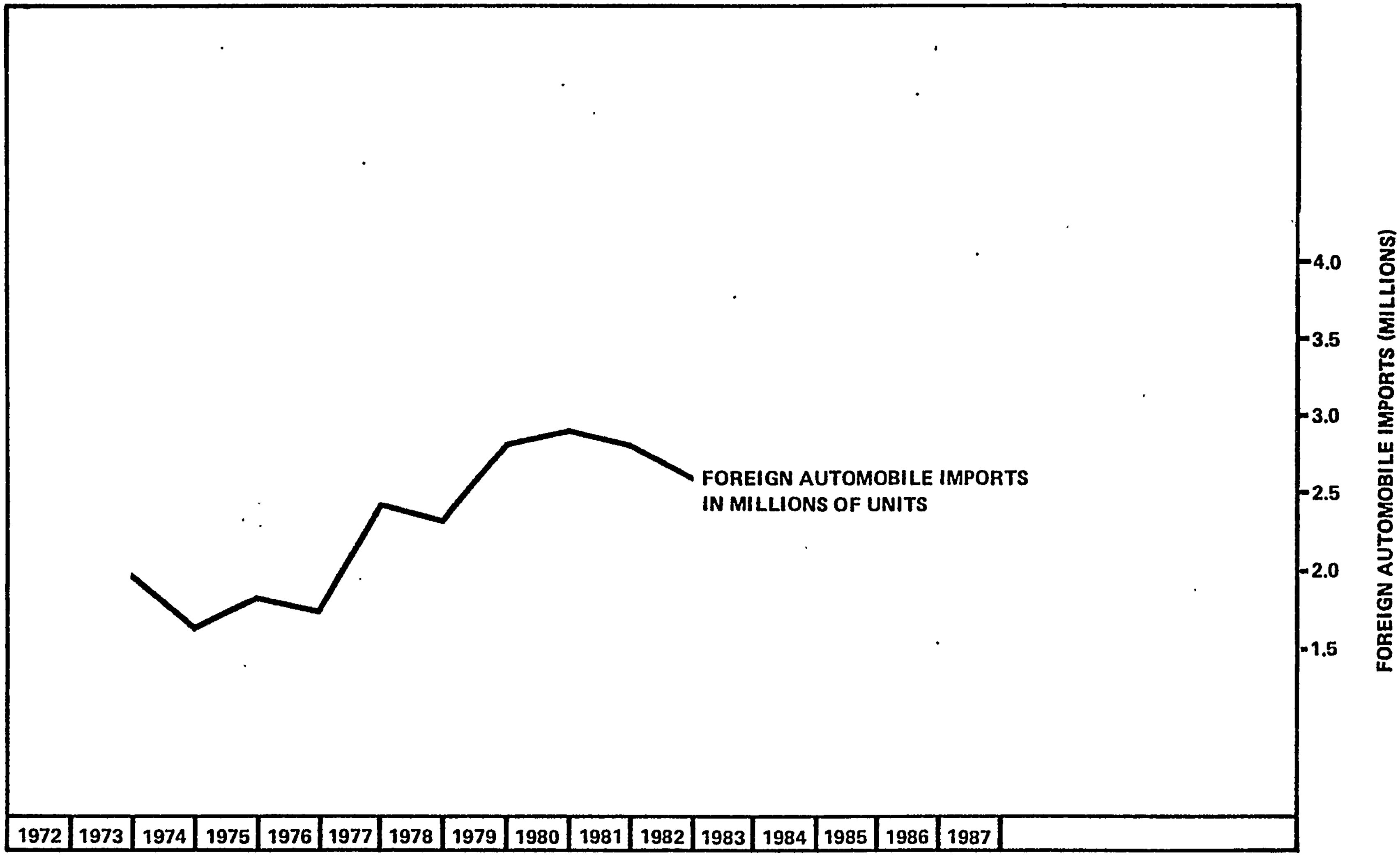
INGALLS Shipbuilding
Litton



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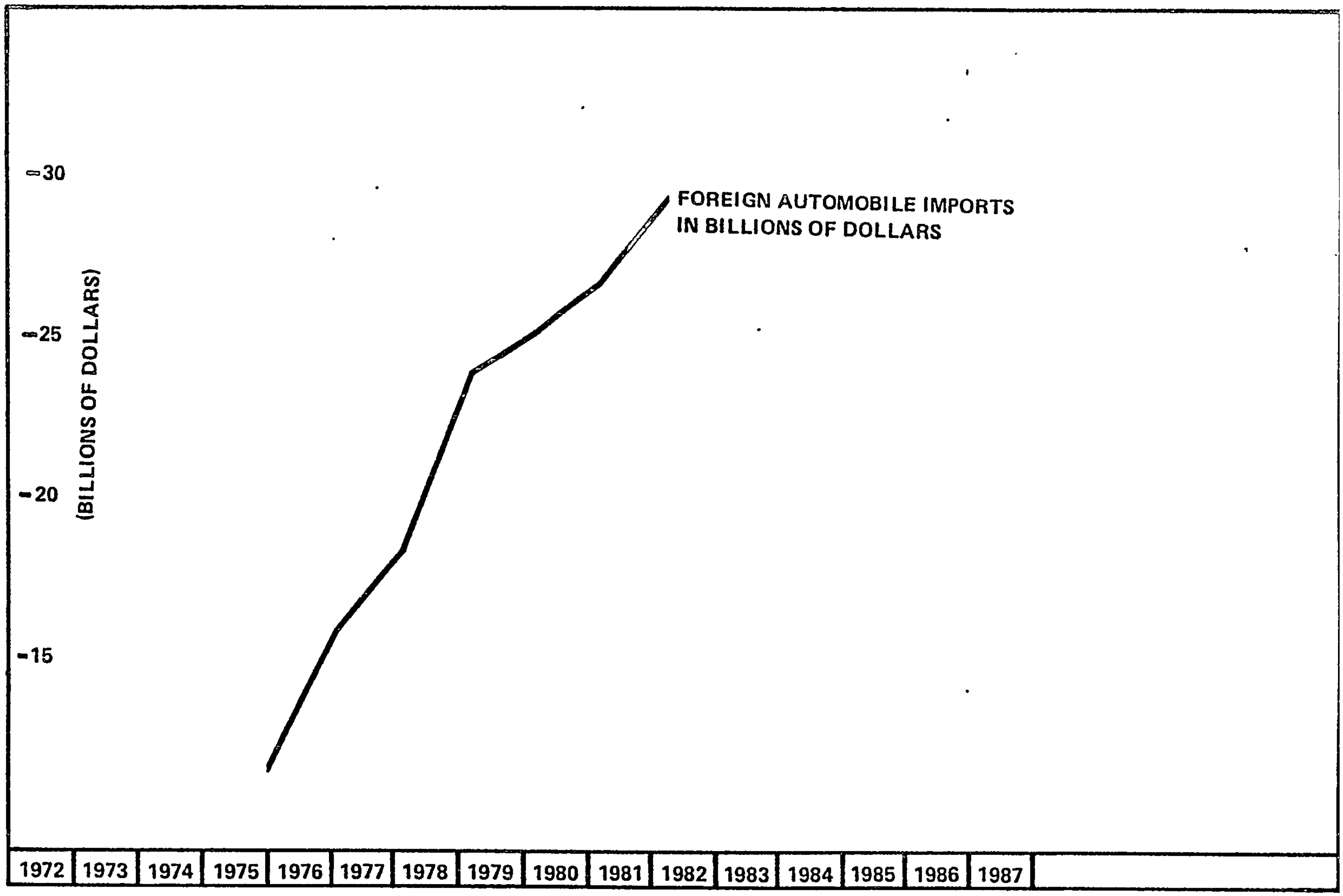
Litton



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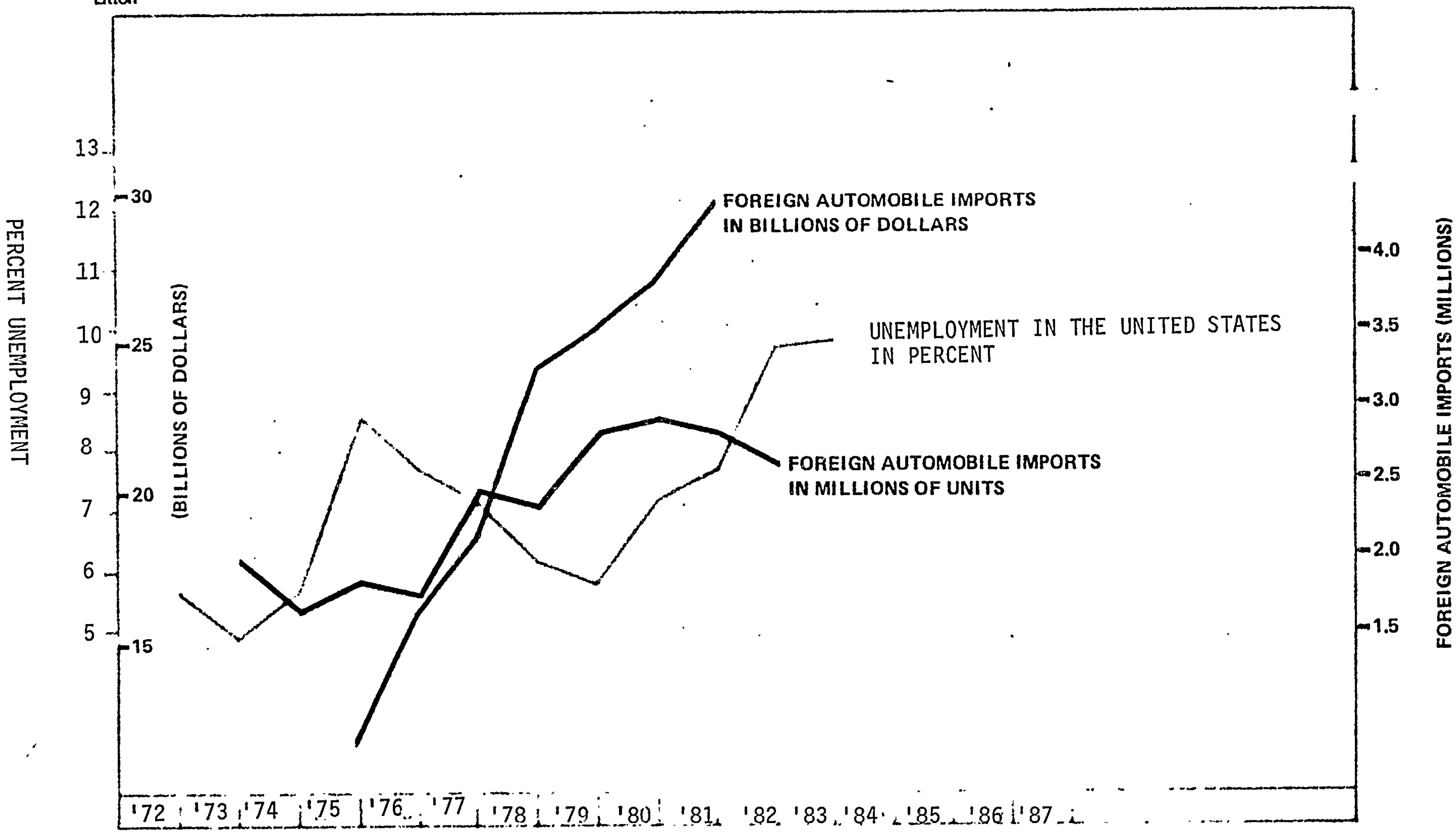
PRODUCTIVITY REDISCOVERED

INGALLS Shipbuilding
Litton



A-0365

INGALLS Shipbuilding Litton

PRODUCTIVITY REDISCOVERED

- APPROXIMATELY HALF OF ALL AUTOMOBILES SOLD IN CALIFORNIA ARE FOREIGN,A HIGHER PERCENTAGE THAN ANY OTHER CONTINENTAL STATE
- THIS YEAR BOTH GM AND FORD HAVE, OR ARE IN THE PROCESS OF CLOSING AUTOMOBILE ASSEMBLY PLANTS IN CALIFORNIA

A-0299

INGALLS
LITTON Shipbuilding
Litton

PRODUCTIVITY REDISCOVERED

SHIPBUILDING IN THE UNITED STATES NEEDS
A BASIS AND A BIAS FOR ACTION

A-0300

PRODUCTIVITY REDISCOVERED

INGALLS Shipbuilding
Litton

FULLY IMPLEMENTING TECHNOLOGY AVAILABLE TODAY IN AUTOMATED COMPUTER CONTROLLED MANUFACTURING EQUIPMENT, BUSINESS SYSTEMS, MANAGEMENT SYSTEMS, AND CONSTRUCTION TECHNIQUES COULD TAKE OVER 5 YEARS

INGALLS Shipbuilding

PRODUCTIVITY REDISCOVERED

- SIX PHASES OF A PRODUCTIVITY PROGRAM
  - NEED
  - CHARTER
  - PLAN
  - ANALYSIS
  - ACTION
  - VALIDATION

PRODUCTIVITY REDISCOVERED

INGALLS
Shipbuilding
Litton

PRODUCTIVITY IMPROVEMENT IS ANY ACTION THAT WILL RESULT IN A BETTER PRODUCT AT THE SAME COST OR A LOWER COST OR THAT WILL RESULT IN THE SAME PRODUCT AT A LOWER COST

PRODUCTIVITY REDISCOVERED

INGALLS Shipbuilding

39

"IT" CAN BE DONE BETTER, CHEAPER, AND EASIER

PRODUCTIVITY REDISCOVERED

INGALLS Shipbuilding
Litton

PRIORITIES FOR APPLICATION OF PRODUCTIVITY IMPROVEMENT

1. MANAGEMENT/MANUFACTURING SYSTEMS
2. CAPITAL INVESTMENTS IN EXISTING TECHNOLOGY
3. DEVELOPMENT OF NEW TECHNOLOGY (ADVANCES IN STATE-OF-THE-ART)

A-0298

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PRODUCTIVITY REDISCOVERED

AUTOMATION CREATES JOBS
AND
SAVES OTHER JOBS

A-0296

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PRODUCTIVITY REDISCOVERED

"... IT IS CRITICAL TO THE SUCCESS OF A COMPANY, THAT COMPANY EMPLOYEES WHO HAPPEN TO BE ENGAGED IN MANAGEMENT ACTIVITIES LISTEN TO AND BE RESPONSIVE TO CONTRIBUTIONS OF COMPANY EMPLOYEES WHO HAPPEN TO BE ENGAGED IN NON-MANAGEMENT FUNCTIONS."

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PRODUCTIVITY REDISCOVERED

BRASHER'S LAW OF PRODUCTIVITY

$$\text{PRODUCTIVITY} = \frac{1}{\left(\begin{array}{l}\text{NUMBER OF PRODUCTIVITY MEETINGS,}\\ \text{CONFERENCES, WRITTEN ARTICLES,}\\ \text{SEMINARS, ETC.}\end{array}\right)^2}$$

A-0293

Litton INGALLS Shipbuilding

PRODUCTIVITY REDISCOVERED

PRODUCTIVITY IS A NEVER ENDING EFFORT

A-0292

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PRODUCTIVITY *REDISCOVERED*

PRODUCTVITY IS RELATIVE; THEREFORE, ATTEMPTS TO MEASURE IT MUST CONSIDER THAT FACT

A-0366

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Litton

PRODUCTIVITY REDISCOVERED

QUALITY CAN BE ACHIEVED IN THE ABSENCE OF PRODUCTIVITY;
HOWEVER,
PRODUCTIVITY CANNOT BE ACHIEVED IN THE ABSENCE OF QUALITY

PRODUCTIVITY ***REDISCOVERED***

INGALLS Shipbuilding
Litton

A CONSISTENT SERIOUS INVESTMENT IN EDUCATION AND RESEARCH ON THE PART OF EVERY COMPANY ACCORDING TO ITS USE OF HUMAN RESOURCES AND TECHNOLOGY IS VITAL TO THE SUCCESS AND CONTINUED SUCCESS OF ANY COMPANY IN WORLD CLASS COMPETITION

INNOVATE ACTION

COST CONCEPTS & PRODUCTIVITY

I. David Gessow
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U.S. Maritime Administration
Washington, D.C.

Mr. Gessow is a naval architect in the Office of Shipbuilding Costs in the U.S.maritime Administration. He is responsible for preparing estimates of construction costs of commercial ships built in the United States. During the past year he has presented two cost related papers: At the SPC/IREAPS Technical Symposium in San Diego, 1982, "Improving Shipyard Productivity by Subcontracting Materials and Labor Within Shipyards", and at the Seventh International Cost Engineering Congress in London, October, 1982, "Estimating Shipbuilding Costs".

ABSTRACT

Productivity and costs are apparently simple and separate concepts. Actually, both are not simple and both need explanations and qualifications to define clearly their intended meanings. They are also related because improvements in productivity must appear finally as reductions in cost.

Improving productivity in shipbuilding requires, in part, measuring an analyzing the application of labor to materials. It also requires analyzing the allocation of other resources to the shipbuilding process. In both instances the unit of measurement is eventually expressed as dollars or other currency.

This paper briefly describes some cost and cost related concepts Which are useful in measuring and understanding productivity.

COST CONCEPTS AND PRODUCTIVITY

I. David Gessow
U.S. Maritime Administration, Washington, D.C.

Cost and productivity are intertwined because increased productivity means less cost and because productivity is frequently measured in terms of cost. Although cost and price are not the same in the economic sense they are in the practical sense that the price paid for something becomes part of the cost of another product when the latter is sold.

The economist's definition of productivity is output divided by input. Thus, when we can make something with fewer people and in less time than we did before, with the same or better quality, the economists say we have improved productivity. If, as engineers and accountants we can report that we produced the item at less than it should have cost, we say that we have improved our production performance.

The different terminology is for two different concepts. Productivity is an "is" measure but it is not a measure of what "should be" Production performance, as developed herein, is a measure of what "is" against what "should be" Stated another way, a productivity value is not a measure against a standard. A production performance value is a measure against a standard. They are the two sides of the same coin.

COST, PRICES, AND THE PRODUCTION PROCESS

The production process consists of converting materials, buildings, machinery, energy, supplies, and labor from one form to another. The Bureau of Labor Statistics identifies, in its Producer Price Indexes, crude goods, intermediate goods, and finished goods.

During its flow the cost per unit of the goods being converted increases. The increases are expressed in the changing prices of the units as they are transferred from one producer to the next. Each increase in price reflects the "value added" per unit to the product and in some countries is a basis for taxes.

We accept these price increases without many questions because we are largely unaware of them. In our personal lives we consume only finished goods and these come to us, within a small time span, in a relatively narrow range of prices. However, when price changes are frequent and upwards, particularly in relation to our more stable incomes, we become aware of "how much more things cost."

As consumers we are primarily aware of the cost of finished goods. In the shipbuilding industry we are more aware of the cost of intermediate goods. For both classes of products it is still difficult to grasp how costs mushroom from the first seller to the last buyer. In shipbuilding, ore, one of the raw materials for steel, is about $33 per ton. From the mill, as an intermediate product, steel is about $600 per ton. When steel is commingled with other intermediate materials of comparable cost the-finished good, a ship, is more than $6000 per light ship ton.

Taking the cost of intermediate materials as $1000 per ton rather than $600, in a ship of 10,000 light weight tons, its material cost-as intermediate goods would be $10,000,000. At $6000 per light weight ton its cost as a finished good is $60,000,000. The difference, $50,000,000, is the cost of labor and capital required for conversion from a collection of intermediate goods to a finished good, the ship. (Intermediate goods are chosen for this example because that is the form in which both shipyard and its suppliers receive materials, and $50 million would be the value added by both shipyard and its suppliers, very approximately.)

Influences on price levels.

The ore at $33 per ton together with other crude materials at about the same price are converted into a finished ship at $6000 per ton. The conversion is the result of application of labor and capital in successive stages. Some of the influences on the increases in cost are the scarcity of the resources used, the technology with which they are used, the influences of government, and underlying all factors, the human needs and wants which cause ships and all other products to be made. Also, threading through all transactions, is the passage of time which almost invariably acts to increase cost.

Initial price level. The initial price level in a society is the starting point for cost increases as goods move from crude to finished forms. That level has been reached because of the cumulative effect of all influences to that time. At a given time the price level represents a balance (albeit an imperfect one) of the money supply and available goods.

Resources. The scarcity of resources determines price levels differently for different products, When a technology is new the-materials, labor, capital, and knowledge needed to produce its products are scarce as crude and intermediate goods and their costs therefore high. As the technology advances and products are wanted their cost as finished goods become less. This has happened in the computer industry. Where the technology is relatively stable over a given time span, as for example in the steel industry, price changes are less rapid and are consistently in one direction because as a basic industry the steel industry directly influences other prices and is in turn, but less directly so, influenced by them. In general, both increasing population and increasing wants of a stable population cause scarcities of resources which increase prices. Recessions and depressions do restrain this upward movement but only temporarily.

Technology. The state of technology and the degree to which that technology is applied influences costs. For example, the development of welding quickly superseded riveting for the assembly of ships. Today welding is available to all shipbuilders. Now, within welding technology, several forms of automatic welding machines and techniques for one-sided welding have been developed. The welded ship is therefore a baseline ship for cost, but those who utilize the more advanced technology within the general technology will generally produce with lower costs.

Government

Government action in the United States increases costs and prices. Taxes raise the overall price level since taxes are a significant element of labor and capital costs at every stage of processing and taxes paid must be recovered in selling prices, Taxes on profits similarly increase the price level. Today it is being said that the government's monetary policy may cause price increases faster than "normal" because it is increasing the supply of money faster than the supply of available goods,

Government subsidies to various producers and its laws and amplifying regulations act to raise prices on specific goods and therefore the general price level. An exception, in the direction of lesser prices increases, may be the government's restraint on monopolies and near monopolies. Local, state, and the national government also compete in the market for goods and services: Together they account for about 20 percent of the Gross National Product. Thus government actions raise prices for all goods and services.

Values

Underlying all production are the needs and wants of individuals and society. They drive production, first to satisfy needs, and soon thereafter to satisfy wants which quickly become indistinguishable from needs, The need for goods to survive creates a floor on prices, and as wants become needs scarcities appear for established as well as new goods, leading to increased prices.

From another aspect, human wants are expressions of human values. Values and economic status determine how much of income is spent and how much saved. This division influences present and future price levels. Collective values also determine the magnitude of government budgets which, as just noted, influence prices.

Time

All individual prices and general price levels take place during the passage of time. Indexes provide reference levels for measurement of their rates of change. Those best known to us are the Consumer Price Index, Producer Price Indexes, and the U.S. Navy Material and Labor Costs Indexes, all prepared by the Bureau of Labor Statistics.

Indexes are necessary to enable prices at one date to be compared and converted to prices at another date. They also enable a stream of prices or expenditures over a period of years to be converted to prices in constant dollars. Where productivity is measured in dollars, comparison in common constant dollars is essential.

Interest for borrowed money increases costs and prices. Some firms also compute an interest cost on capital owned and include an amount for it in their costs. (Borrowed money is a good example of how scarcity of resources increases costs.) Today, interest cost of borrowed money is said to have two components: one of pure interest for the use of money and one due to inflationary expectations.

It is interesting to examine the term inflation. In the normal sense it means distended or expanded. With respect to prices it implies a level which is higher than that attributable to the quantity of goods then available. That impression coincides with one economic definition of inflation as "An abnormal increase in available currency and credit beyond the proportion of available goods, resulting in a sharp and continuing rise in price levels"(1)

Economic concept of cost

An economic definition of cost has been provided by the Financial Accounting Standards Board (2):

> "Cost is the sacrifice incurred in economic activities--that which is given up or foregone to consume, to save, to exchange or produce, etc. For example, the value of cash or other resources given up (or the present value of an obligation incurred) in exchange for a resource measures the cost of the resource acquired. Similarly, the expiration of future benefits caused by using a resource in production is the cost of using it."

An economic definition of price is more complex; it expresses the relationship between supply and demand.

The FASB definition of cost is in line with the view that economics may be summarized for an individual by two questions. "What is it worth to me?" and "What do I have to give up to get it? By simple extension, the number of dollars given up or received is termed the cost to the purchaser and the selling price to the seller.

The central problem for both buyer and seller is how many dollars to require or to pay in exchange for the resources expended or acquired. Since each has many exchanges at about the same time and each exchange generally represents a mixture

of resources the question confronting each side in all transactions is how much of the total resources processed by each should apply to a specific dollar transaction. In simple terms, how is cost determined? The answer to that question is in the province of accounting.

Accounting

Accounting systems are designed first to record costs and then to form streams of costs which merge into subtotals and totals which separate into other streams to form the final categories of subtotals and totals.

This flow of accounts measures costs because:

a. It records all costs to the firm as they are incurred.

b. It identifies and groups expenditures similar in purpose.

C. It allocates costs from among similar groups of expenditures to different cost objectives.

d. It allocates costs incurred to specific periods of time.

Accounting is generally regarded as being concerned only with costs which have already been incurred, although its methods may be used for prediction of future costs, as for example estimation of replacement costs of assets. Note though, that allocation of past costs to the future, by asset accounting techniques, is part of conventional accounting.

From the viewpoint of production performance, the significant function of accounting is that of allocating costs.

Since accounting is not only an internal matter for a firm but affects virtually all business transactions among firms and between firms' and government, standards for reporting business costs and performance have come into effect.

a. The Financial Accounting Standards Board, the designated organization of the private sector for establishing standards of financial accounting and reporting has issued over 150 standards, interpretations, and reports. FASB standards are accepted by the Securities and Exchange Commission for its regulations. The few areas not so covered are supplemented by the SEC in its Financial Reporting Releases,

b. The Department of Defense has issued Defense Acquisition Regulations (DAR) which have the force of law for its purchases. (These have been known as ASP, Armed Service Procurement Regulations). The DAR appear in the Code of Federal Regulations as CFR32.

C. The Cost Accounting Standards Board, CASB, established by Congress has written standards for procurement by all Federal departments including the Department of Defense, The Board no longer exists but the standards remain in effect and appear in the Code of Federal Regulations as CFR4. The latest issue of this Code is January l, 1983. The Defense Department's regulations in CFR32 follow the CASB standards.

The financial standards deal with costs, but their main concerns are balance sheet and profit and loss statements. The purpose of the CASB and DAR standards is to insure that contracts between the U.S. Government and private firms are

based on costs which apply only to specific contracts. The standards require disclosure of internal accounting practices, but do not. specify which practices to follow. They do prescribe consistency and they do set rules for allocation of some overhead costs to specific contracts. Because the U.S. Government contracts mostly for manufactured goods, the CASB and DAR standards constitute useful references to manufacturing cost accounting practices.

PRODUCTIVITY

> "Productivity is the source of all economic value."
> Peter Drucker (10)

BLS measures of productivity

The source of data on productivity in the U.S. economy is the Bureau of Labor Statistics. Productivity is reported as output in dollars per hour. For manufacturing firms, the numerator (output) is its share of the Gross National Product in dollars, and the denominator (input) is the labor hours for its production. The Technical Note in each release (3) defines the relationship between output and input:

> "The productivity and associated cost measures in this release describe the relationship between output in real terms and the labor time involved in its production. They show the changes from period to period in the amount of goods and services produced per hour. Although these measures relate output to hours of all persons engaged in a sector, they do not measure the specific contribution of labor, capital, or any other factor of production. Rather

> they reflect the joint effects of many influences, including changes in technology; capital investment; level of output; utilization of capacity, energy, and materials; the organization of production; managerial skill; and the characteristics and effort of the work force"

In April 1983 BLS introduced (4) two measures of productivity to supplement the overall measure: Both are intended to account for the contribution of capital to productivity,

a. Multifactor productivity, the output in dollars divided by combined labor and capital services input.

b. Output in dollars divided by capital services input in dollars.

For these new measures of productivity the capital services input is developed as explained in this quotation from the BLS release:

> "The capital services component of the combined input indexes is developed from measures of the stock of physical assets--equipment, structures, land, and inventories--and rental prices for each type of stock. The stock measures, in turn, are derived from data in the national accounts and other sources of investment, service lives, and capital deterioration functions. The rental prices are derived from data on depreciation costs and estimates of rates or return on the capital assets,"

Both BLS definitions suggest that productivity may be viewed as a function of two groups of factors: tangible and intangible, Tangible factors are those which are directly measurable in dollars. Intangible factors also determine productivity but are not quantifiable in simple units.

It is interesting to speculate on the relative contribution of tangible vs. intangible factors to productivity. Where raw material costs and living standards

(price levels) are approximately the same for firms and countries their relative productivities may well be determined principally if not wholly by the intangible factors present in each. Further, within a firm and among similar firms in the same society, intangible factors probably determine relative costs more than do tangible factors.

Productivity in the shipbuilding industry

The literature of the shipbuilding industry has many discussions of productivity but few on how to measure it. Those that do are the Webb Institute Report of 1969 (5), and the 1973 Report of the Commission on American Shipbuilding (CAS) (6).

Earlier discussions of accounting for shipbuilding costs which still have much value fOr today appear in William B. Ferguson's "Shipbuilding Cost and Production Methods" (7) published in 1943 but reprinting material from his earlier book of 1915. The SNAME volume "The Shipbuilding Business in the United States of America, Volume II" (8) published in 1948 contains two valuable chapters: "Shipyard Cost Keeping and Cost Accounting" by W.B. Ferguson and B.V. Tornbough, and "Corporate Accounting and Management Controls" by M.F. Pixton, of Ingalls Shipbuilding.

The REAPS reports on shipyard production methods offer much information on methods of improving production but do not offer any methodology for measuring it.

A recent report, Productivity Improvements in U.S. Naval Shipbuilding, prepared for the National Research Council (9) includes the statement that "The purpose of this repoKt is less to measure and evaluate productivity than to recommend how it may be improved."

CAS measures of productivity

The report of the Commission on American Shipbuilding discusses in detail measures of productivity in shipbuilding:

> "Productivity is a measure of the output of a process per unit of input, i.e., a measure of the efficiency with which the input is utilized to produce the output."

Productive efficiency was defined in terms of compensated gross registered tons (crgt) as output and cost of labor and capital as input. The specific measures used in its analysis were cgrt Per (a) employee, (b) labor dollar, (c) capital investment dollar, and (d) total labor and capital dollars.

Other measures of input and output are suggested in the report and are tabulated below. Asterisks have been added to identify the measures expressed as costs.

output
- Industry or shipyard wide
  - *Sales or revenue per unit time
  - Production volume (CGRT, DWT, GRT, etc.) per unit time
  - *Value added per unit time
  - Steel throughput per unit time
  - *Total cost (direct and indirect) per unit time
- Ship particular
  - *Price or cost of ship (type and size)
  - Steel per ship (type and size)
  - Outfit (and other subsystem) weight per ship (type and size)
  - SHP (installed, etc) per ship (type and size)
  - *Value added per ship

Input

Industry or shipyard wide

*Cost of resources used (material, labor, services, - tax, land use, working and investment capital costs)

*Cost of capital employed (depreciation, rental value, etc.)

*Labor (number of employees, hours, costs)

Ship particular

*Cost of resources used

*Capital costs, as above

*Labor, as above

Present shipyard cost accounting systems

Most U.S. shipyard cost accounting systems can readily provide data for the foregoing measures of productivity. A brief description of a typical system is:

a. The main cost accounting unit is the ship. Sub-units are the cost groups which define the components of the ship.

b. Actual costs are charged to each cost group of each ship in these categories: direct material, direct labor, and other charges. In general, direct material is that which forms a permanent part of a ship and direct labor is labor performed on direct material. Other charges are services and materials known to apply specifically to a given ship.

c. All other costs are allocated to overhead accounts of which there are at least fifty. Sometimes there are general and administrative accounts separate from the overhead accounts.

d. The total shipyard overhead dollars for a period are divided into the total direct labor hours for the same period and the result is overhead in dollars per direct labor hour for that period. (Overhead ranges from 90 to 150 percent of direct labor.)

e. The total cost of a ship is the sum of direct material, direct labor, overhead per period over all the construction periods, direct charges, and, if separately recorded, an amount for general and administrative expenses, allotted on some basis related to the other costs of the ship.

. The advantages of this accounting system are:

1. Most direct materials and most direct labor costs are known for cost group and total ship levels.

2. The overhead allocation, on the basis of labor hours is simple to apply, and capital costs can be isolated.

3. Valid comparisons of inputs of direct material and direct labor for the same cost groups can be made among precisely similar ships if all elements governing cost and productivity are precisely the same for these ships. The differences, after excluding nonrecurring costs, provide information on learning and, since all elements are never the same, on the effect of some of the intangible factors.

The disadvantages are:

1. During the stages of production, production performance is not measured.

2. Comparisons between different manufacturing methods are difficult

3. For intermediate products, in addition to the direct costs, other costs such as capital have not been allocated; their total costs are therefore uncertain.

Proposed new method to measure productivity

> "When you can measure what your are speaking about, and express it in numbers you know something about it, but when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind: it may be the beginning of knowledge but you have scarcely, in your thoughts, advanced to the stage of science."
>
> William Thomson, Lord Kelvin
> Popular Lectures and Addresses, 1891-1893

The specific measures of productivity used in the report of the Commission on American Shipbuilding have but one measure of output, compensated gross registered tons. Thus only the productivity for a completed ship is available. But measures of productivity at all stages of ship production are needed if knowledgeable progress is to be made.

I believe that a system to measure production performance at all stages of production can be built around the concept of a "cost objective" as defined by the CASB and a cost accounting system based on absorption costing and standard costs. Definitions of these terms follow.

Cost objective. The Cost Accounting Standards Board defines a cost objective as:

> "A function, organizational subdivision, contract, or other work unit fOr which cost data are desired and for which provision is made to accumulate and measure the cost of processes, products, jobs, capitalized projects, etc."

So defined an objective is not limited to something tangible; it may be a function (making one item or assembling several items), or an organizational subdivision (a ship or zone assembly station). The number of objectives in a shipyard is therefore limited only by the level of detail wanted for analysis, by computer capacity, and by acceptable cost.

The CASB defines specific and final cost objectives. The proposal would add the terms "unit" and "intermediate" cost objectives to establish a hierarchy of objectives leading to the final objective.

Cost accounting system. An accounting system specifically designed to measure manufacturing costs.

Absorption costing. Absorption costing is followed when in addition to direct material and direct labor, all other costs incurred in a manufacturing plant are allocated on a predetermined basis to specific products instead of to an overhead account. In the proposed method the term "specific products" would be replaced by "cost objectives."

Standard costs. Standard costs are benchmark or reference costs against which actual costs, i.e., those actually incurred are measured. Standard costs are established either by engineering studies, or initial experience, or a combination of both. They are "should" costs and are developed for a given level of production in a plant. They are periodically revised to correspond to experience and progress. In the proposed system standard costs would be developed for each cost objective. As Work progresses through a shipyard standard costs are charged to it, as are actual costs.

Actual costs. A cost accounting method, which when used with cost objectives, follows absorption costing practice.

Terminology

Measuring production in terms of cost objectives, standard costs, and actual costs requires that the term "production performance" be used instead of "productivity":

1. Production performance is defined only in terms of cost objectives which may be unit, intermediate, or final. Each production performance measure refers only to the cost objective for which it is defined,

2. Production performance may be defined for only material cost, labor cost, capital cost (in its various forms), or any combination of cost objectives. All costs are to be expressed in constant or "base" dollars as well as in current dollars.

3. Production performance variance of a cost objective is the standard cost minus the actual cost of a cost objective. A positive variance means that actual production incurred a

specific number Of fewer material dollars or labor hours or total costs (material plus labor plus capital) than set by the standard. A negative variance means just the opposite, (Production performance variance may be material variance, labor hour variance, etc. for any cost objective.)

4. The Coefficient of Production Performance of a cost objective is a dimensionless measure obtained by dividing the standard cost of a cost objective by the actual cost of that objective. If the actual cost is more than the standard then the coefficient is less than one; if the actual cost is more than the standard then the coefficient is less than one, In both instances, the higher the coefficient with respect to 1.0, the higher the production performance, and the further below 1.O the less the production performance.

5. The term “efficiency” is not used with these definitions. It is superseded by the Coefficient of Performance which can be more than 1.0.

Defined in the foregoing way production performance is a very specific term, but one which may cover wide territory. For example, a complete ship may be a final cost objective. To compare production performance of different ships the cost objective for each would be compensated gross registered tons.

Proposed shipyard cost accounting system

The proposed cost accounting system would be added to existing systems; it would not replace them. As either an added or a new system, its elements are:

a. Present cost accounting systems are integrated into the classification system based on cost objectives.

b. Present accounts are reclassified into direct and indirect accounts and respective subaccounts. Each subaccount has as many cost pools as necessary. Costs from these accounts, both actual and standard, are charged to cost objectives. The proposed classifications below is taken from the CASB disclosure statement

- Direct costs
  - Material
  - Labor
- Indirect costs
  - Overhead
    - Manufacturing
    - Engineering
    - Other
  - Service center
  - Depreciation and capitalization
  - Insurance and deferred compensation
  - Other

c. Standard costs are established for those cost objectives deemed necessary to measure production performance as defined above Each standard cost has included in it a calculated share of the total manufacturing budget for the accounting period, broken down into each of the direct and indirect costs attributable to it in an absorption system of accounting for costs. Specifically, capital charges are included where appropriate.

d. As work progresses through the plant both actual and standard costs are charged to cost objectives via properly designed job tickets which provide for accumulating and transferring costs of work-in-process. For actual costs the direct material and labor charges are applied as incurred; indirect costs are charged at the end of each accounting period in the same ratios as are the standard costs.,

e. At appropriate accounting periods, preferably no longer than monthly, actual and standard costs are compared.

The foregoing system requires much work of which establishing the standard costs is the greatest portion. But the steps in doing so would be invaluable because intensive examination of production processes will, by itself, lead to improvements,

Setting cost objectives is another major task. This is One which should be done by an industry wide group. It would be advantageous if a uniform system of ship costs were established and made part of a system of cost objectives.

It is not necessary for the standard cost system to be set up at all once. It could be introduced in parts and expanded as experience is gained. But the set-up work is not important. What is important is being able to measure production by comparing actual costs against standards for clearly defined objectives.

Once standards have been set and "actual" is measured against "standard," we have the engineer’s and accountant's way to increased productivity.

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ENHANCING PRODUCTION MANAGEMENT CONTROL THROUGH PERFORMANCE MEASUREMENT

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ABSTRACT

One of the key issues today in all business environments is the enhancement of productivity. Production Management Control is the cornerstone of the attainment of optimal productivity. This paper will identify ways that the manager can periodically monitor the progress and performance of the shipbuilding effort throughout the construction cycle. The main thrust will center around the analysis that can be performed on the information generated from the cost/schedule control systems criteria system and intergrated with the more traditional networking and quantitative construction data.

I. INTRODUCTION

Production management takes place in a dynamic environment where plans, schedules and resources are continually changing. It involves a never ending challenge to fine tune and adjust plans and control inputs with the goal of obtaining the contract objective. Management of a shipbuilding program is no exception. The complexity of the product, the magnitude of the resources involved, and the time required to construct a ship all contribute to the high level of difficulty involved in managing the production process.

To manage a process as complex as shipbuilding, there must not only be excellent planning, but there must be continual tracking of progress against schedule and goals with reprogramming as necessary. Rather than always being in a reactive mode, potential performance problems must be identified early enough to permit changes which will control schedule slips *or* cost overruns.

Performance measurement is the process of measuring key production parameters against established goals and targets. Initially, these goals and targets are set to reflect management's best estimate for desired outcome. The comparison of actual performance against the preset targets and goals enables the manager to assess progress as well as identify problem areas. Through this early indication of potential problems, significant long term unfavorable trends can be avoided.

This paper identifies systems and techniques that can be utilized by the shipbuilder to assess his own progress and performance more accurately. Accurate performance measurement is essential to production management control. Without this vital feedback, plans and goals could become meaningless.

II. MEASUREMENT INFORMATION SYSTEMS

In most circumstances requiring a decision, there exist knowns and unknowns. The rational decision maker will reduce the uncertainty or risk to the greatest extent possible and then make the most logical decision based upon the facts. This reduction of risk is the basis for instituting formalized management information systems. Without a structured system for collecting and interpreting data, the decision maker will either be overwhelmed with an abundance of detailed data or will have very little information from which to make a sound decision. The formalized management information system provides a framework for systematically evaluating significant production parameters without having to rely totally upon expertise or conjecture. Department of Defense Instructions 7000.2 "Performance Measurement for Selected Acquisitions", June 10, 1977, and 7000.10 "Contract Cost Performance, Funds Status and Cost/Schedule Status Reports," August 6, 1974, dictate the use of specific management information systems for selected acquisitions. These instructions require use of the Cost/Schedule Control Systems Criteria (C/SCSC) for most major acquisitions. They state that the objective of the C/SCSC is:

"To provide an adequate basis for responsible decision making by both contractor management and DoD components. The contractors' internal management control systems must provide data which: indicate work progress; properly relates cost/schedule and techical accomplishments; is valid, timely and auditable; and supplies managers with information at a practicable level of summarization."

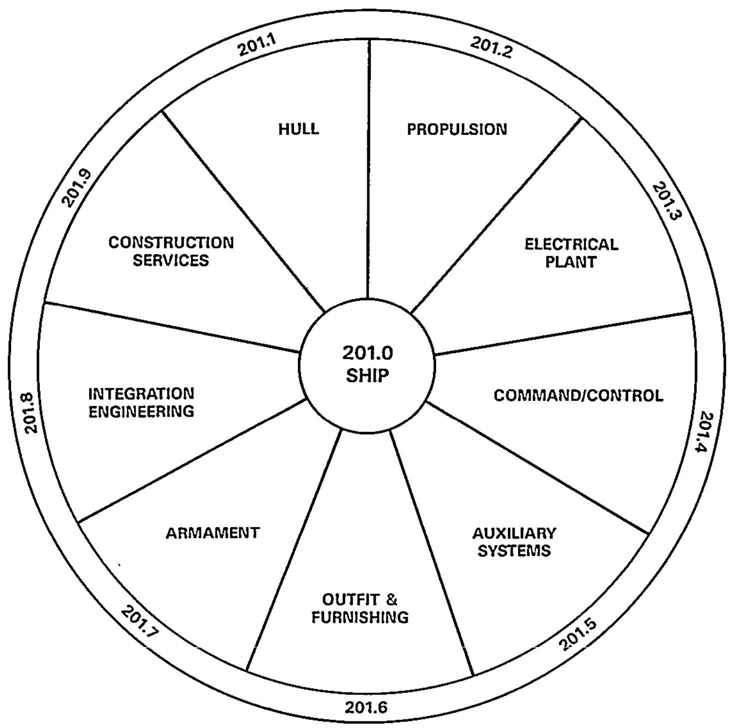
The contractor's management information and control system must be structured to facilitate the integration of plans, schedules, budgets, work authorization and cost accumulation systems with each other, the Contract Work Breakdown Structure (CWBS), and the internal organizational structure. It must record both direct and indirect costs and allocate them to the appropriate CWBS element as well as the performing organizational element. The system should generate on a monthly basis, scheduled earned and actual values for labor, material and indirect costs associated with the appropriate CWBS element as well as the contractor's internal organizational element. This information takes the form of either a Contract Performance Report (CPR) or Cost/Schedule Status Report (C/SSR). The CPR is a formal management report which displays summary level cost and schedule performance data and funding data for purposes of Program Management. The CPR is required for major defense systems acquisitions which are defined by Department of Defense (DoD) Directives 7000.1 and 5000.1. The C/SSR is also a management report which displays summary level cost and schedule performance data on "non-major" defense systems acquisitions. The C/SSR is used in place of the CPR for programs that are not designated by DoD Directive 5000.1 as major defense system acquisitions.

ELEMENTS OF PERFORMANCE MEASUREMENT

Primarily, performance measurement can be implemented by the integration of defineable and manageable units of work within a framework of a product oriented work breakdown structure. This structure as shown in Figure 1, should also be integrated with the shipyards' organizational structure to establish functional responsibility for identifiable units of work. This integration will be accomplished at the cost account level. Assignment of functional responsibility, cost collection and ultimately performance measurement analysis can be conducted at this level. Major elements of this approach are work scheduled or budgeted on a periodic basis (BCWS) versus work performed (BCWP) compared to actual hours or costs expended (ACWP). These elements could be identified in units of hours and/or dollars which may include the materials measurement process as well. Figure 2 shows how planning, budgeting and scheduling all interrelate for the development of baselines which form the basis for performance measurement.

FIGURE 1

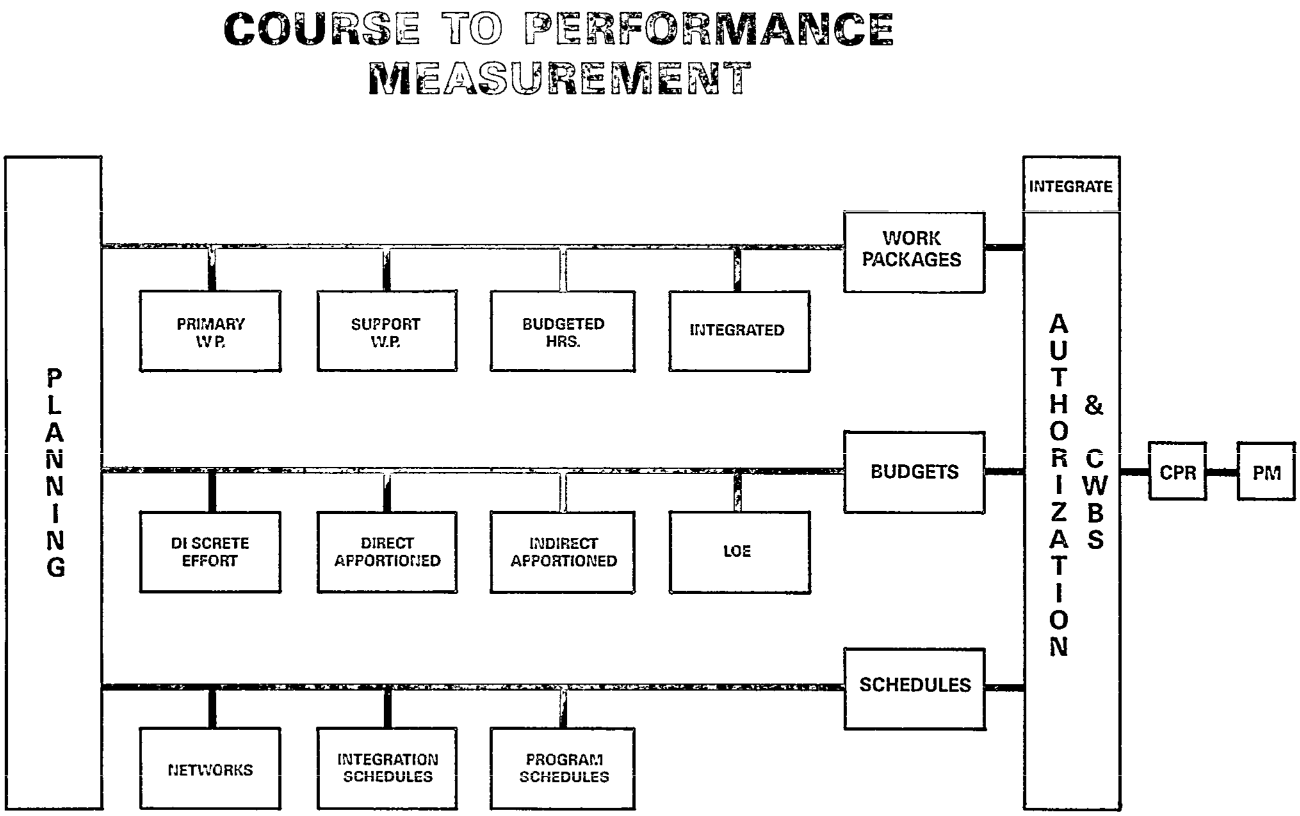
PRODUCT ORIENTED WORK BREAKDOWN STRUCTURE



Planning

During initial planning, authorized work should be reduced to increments of work (cost accounts). The cost account structure forms the basis for work authorization, budgeting, and top level scheduling efforts. As this work is refined and planned in detail, work packages are identified and assigned to successively lower levels of functional management as determined necessary, by the shipyard. Plans should include appropriate lead time for work package development prior to release for production. Initially, planning and budgeting should occur down to the cost account level. As detailed planning proceeds, the authorized effort should be budgeted down to the work package level. For work that is authorized, but unpriced, planning and budgeting should be a near-term effort placed into the cost accounts, while the remaining effort should be planned and budgeted at higher levels of the work breakdown structure. Upon adjudication of any changes to the contract baseline, the additional effort authorized by the change shall be planned and budgeted at the cost account level as soon as practicable.

FIGURE 2



Work Package

To be effective for planning and controlling work9 a work package format is required and should have several basic characteristics in order to allow it to be cost accountable,

Q It must be a natural product of the planning and budgeting activity.

Q It must have definable units of work at a manageable performance level. Of all the characteristics, this one is a major driver because it is the product of the experience and discrete knowledge of the facilities/capabilities and construction methods of the shipyard. The success or failure of production performance depends heavily on this development.

Q It must be assignable to an organizational element (trade or craft). This item will be driven by work package definition and there will be instances when it will be an arbitrary decision as to which trade will be assigned the lead because of work package content.

Q It must have scheduled start and finish dates with interim milestones which support physical progress monitoring of the work

package. Ideally, work packages should be scheduled to complete within one reporting period to allow more accurate status accounting and performance measurement. Work packages spanning several reporting periods should rely on precisely placed milestones for interim progressing. For shipyards with the capability, networks can be keyed with work packages or groups of work packages to permit management verification as the program moves through it's phases of time.

Q Packages should be classified to distinguish between Primary and Support work packages.

Q Budgeted values should be expressed in manhours.

Q Integrated scheduling with engineering, material availability and construction is an obvious requirement in this process. Here, particularly, networking would be of major significance in planning validation.

Primary work packages should be for work items dealing with fabrication, installation and testing and reflect work of the lead craft or trade. Support or level of effort work packages should be segregated from primary or discrete work packages to avoid distorting work that is clearly measureable. Since support work can only be measured through the passage of time, budgeted work and performed work will always be equal.

Budgeting

Components of the budgeting process that provide the basis for cost/ schedule performance measurement are the work authorization and the classification of the work effort. Elements of the work authorization are: work breakdown structure, work package, program labor and material, vessel labor and purchase requisitions. The classification of the work effort includes the discrete effort, apportioned effort and level of effort (LOE).

The discrete program task effort is non-recurring. The results of these tasks provide the details needed to accomplish vessel task efforts. Discrete engineering effort is primarily drawings, test procedures, procurement specifications and technical manuals. The effort required to initially issue this data is defined as discrete effort. It is constrained by the nature of the task; each task having the necessary elements of measurable units, i.e., drawing milestones and associated budget hours, scheduled start and scheduled completion dates. The discrete vessel task effort consists of recurring effort that is readily associated with prime hardware fabrication, installation and/or test and is normally recurring in nature, e.g., assembly, module erection, etc.

Direct apportioned efforts are tasks, which by themselves, are not directly schedulable. Their schedules are determined by the tasks which they support. Included in this category are efforts such as construction services, supervision, and quality assurance. Indirect apportioned efforts (overhead) are the pools, established for the collection and distribution of overhead and G&A Costs.

LOE is work that (1) does not meet the criteria for discrete or apportioned effort and (2) is measured only in terms of resources planned to be consumed in a time-phased, budgeted rate of consumption. LOE activity is treated differently than discrete effort. While discrete effort can be measured based on the completed pieces of work, LOE is measured through the passage of time. When practical, LOE activity is segregated from discrete effort to avoid distorting that which is measurable.

Indirect cost estimates are prepared on an annual basis, After review and approval by management, those estimates form the indirect budgets for the organizational units. The approved budgets are summarized at each successively higher organizational level to provide the visibility required for effective planning and control by each responsible level of management. Indirect costs are labor, material, services, supplies, and other costs which cannot be specifically, economically and consistently identified to a particular cost objective. An item which lacks controll= ability of final consumption from the point of origin is classified as an indirect cost.

Resource budgets are established to meet contract objectives identified in the Contract WBS. Since it is impossible to complete detail planning, scheduling and budgeting immediately after contract ahard, it is necessary to utilize an undistributed budget. Initially, when the PMB is established, the undistributed budget is placed in a unique CWBS and time-phased to the extent practical. As detailed work statements are scoped, budgeted, and released, the undistributed budget is relieved. For Vessel Labor, after the ship has been fully scoped and budgeted, the Performance Measurement Baseline (PMB) will be reallocated to assure consistency of budgets between cost centers and accounts. After this allocation has been accomplished, PMB budget should not be reprogramed.

The contract budget baseline is the contract cost, plus the estimated cost for authorized changes at the WBS level required by the contract, including labor, material, and overhead. This baseline will be modified only by contractual change or formal reprogramming actions done with the cognizance of the procuring activity. The PM3 is the time-phased budget plan against which contract performance is measured. It reconciles to the target cost at the total contract level. This is the baseline used to report contract performance to management. Revisions to the budget baseline can reflect mutually agreed changes to the contract or can compensate for cost, schedule, or technical problems which require a reorganization of work or people to increase efficiency of operations. Revisions can also be the result of a different engineering, manufacturing or logistics approach than originally contemplated, or a make-or-buy decision which caused work to be transferred between direct rates or a shift in cost elements within the same directorate (e`. g., from labor to material or vice versa).

Contract changes can impact virtually all aspects of the internal planning and control system. Where the change has been negotiated and priced, budget ledger revisions are based on the value of the change. Where work is authorized prior to negotiations on an executed not to exceed priced contract modification, internal budgets are established as a percentage of the cost estimate for the change.

Budgeted Cost of Work Scheduled (BCWS) is developed for each task by integrating task budget data with such related schedule indicators as planned activities, events, and task statements. The sum of the budgets for all work packages, planning packages, etc., (including in-process work packages), plus the amount of LOE and apportioned effort scheduled to be accomplished within a given time period produces the BCWS. Budgeted Cost of Work Performed (BCWP) is the sum of the budgets for completed work packages and the completed portions of open work packages, plus the appropriate portion of the budgets for level-of-effort and apportioned effort.

At the discretion of the company management, management reserves may be withheld prior to budget release. Reserves established for contingency or management control purposes are clearly segregated from unreleased budget. When management reserves are used to cover additional costs anticipated as a result of authorized changes other than a contractual change in scope, records should clearly indicate when and where management reserves are applied.

The Estimate at Completion (EAC) consists of actual costs to date, plus the Estimate-to-Complete (ETC) all remaining effort. Initially, the original budget baseline and the EAC baseline are the same. When work on a given contract is started and actual costs are charged to that contract, the EACs thereafter are adjusted to reflect baseline or performance changes.

Scheduling

The schedule planning process should utilize traditional scheduling techniques such as networks, milestone schedules, Gantt charts and tabular presentations which portray schedule performance status in terms of calendar dates and ahead-or-behind schedule time frames. Shipyard Integration Schedules should be developed to interrelate major activities. Program Schedules are then developed from the Shipyard Integration Schedules. Subordinate schedules are then developed in support of the Program Schedules. Program and detailed networks should be maintained as an integral and major part of the scheduling system to provide the time-dependent interrelationships and constraints for the activities which support the milestones described on applicable work. They should also be maintained to facilitate detailed schedule planning which concentrates visibility on the work immediately ahead and serves as the coordinating schedule for all other detailed schedule preparation.

The program schedule system requires iterative planning in the identification of major milestones and key interface events and in the preparation of detail level plans. The basic schedule levels include: Program Schedules covering the complete program time span; Networks covering each of the primary functional groups or ship units, and Product Integration Schedules which coordinate the schedules for drawings and test plans keyed to the required need dates to support release of detailed work authorizations for ship construction.

Program Schedules

- 0 Key Event Schedule, The key event schedule by hull, expands and establishes milestones for the Program networks. The number of events should depend on the complexity of the program.

- 0 Facility Loading Schedule. The Facility Loading Schedule establishes the time and location of each hull in major work areas of the shipyard.

- 0 Product Integration Schedules. This level of scheduling plans the work authorization time-phased requirements between and within functional organizations for construction of the ship. Detailed vessel labor requirements are forecasted from system/ contract drawings and specifications. Each package is identified within the framework of an accounting system and category of work, such as manufacture, preassembly, installation, test or support. The schedule is determined by its relation between specific events identified on the networks.

  Supporting groups are scheduled using appropriate overlapping.

- 0 Engineering schedules are identified from requirements identified by system/contract drawings and specifications. Schedules for drawing preparation and release are developed and coordinated to support production requirements. Engineering develops the drawing index concurrently with construction networks. In addition, material/equipment procurements are scheduled so that vendor design information is available to Engineering on a timely basis to support development of Engineering drawings. Test agenda are identified and scheduled to support the program networks,

Networks

- 0 Depending on a shipyard's size and complexity, a Program Summary Network may be desireable. The Program Summary Network contains key events from each of the Program Networks giving an overview of the total program.

- 0 The Program Networks cover major functional categories; namely, Hull Construction, Engineering, Test and Evaluation, Integrated Logistics Support (if required) and Program Management. Major subcontractor and interdivisional work authorization key events are time sequenced with appropriate prime contractor events.

- 0 The Ship Construction Pert Networks provide graphic schedule and critical path display of interacting shipyard task effort. These networks provide by ship system the necessary parameters to perform the scheduling of groups. These networks include the Key Events from the Master Construction Schedule for the specific ship as well as the Major Events related to vessel labor.

All network and milestone displays should be statused on a periodic basis. The critical path exhibits and related analyses are presented to top level management. The milestones and activities reflected in the network plans should be correlated with those displayed in the work authorization milestone schedules. Specific expected performance dates should then be established and used as a basis for monitoring program schedule performance.

Material procurement and in-yard need schedules are developed within the framework established by the aforementioned networks, drawing issue schedules, and the construction schedules. Supplemental schedules developed by functional organizations will be provided through detailed planning for raw materials, construction services material and other direct costs. As the contract progresses, specific required in-yard dates or milestone billing plans for procurements will be substituted for the initial planning schedule and become the time-phased performance measurement baseline for those procurements.

The scheduling process is accomplished sequentially, progressing from top levels to the detail level. Manpower requirements are progressively refined as the planning and scheduling details are established. These requirements can be time-phased utilizing computer programs. Manpower availability constraints are programmed to identify schedule support incompatibilities. Similarly, facility loading is continuously monitored to identify potential overloads in the scheduling process. The scheduling process is repeated as required to eliminate incompatibilities.

Assessment Analysis

A formal cost accumulation and reporting system should be established with the capability of providing valid, auditable, and timely cost/ schedule performance. Cost and schedule variances are positively identified analyzed and appropriate corrective actions taken. Incurred costs are summarized from the lowest cost collection levels to the contract reporting levels. Indirect apportioned costs are collected and allocated to the applicable base(s) in accordance with existing accounting procedures. Once recorded, incurred costs are not subject to change except for correction of errors to reflect normal accounting adjustments. Direct costs are accumulated on an incurred basis and in a manner consistent with the way these costs are budgeted.

Monthly reports should be published indicating the actual versus budget status for the current reporting period as well as cumulative-to-date. These reports detailed by the individual expense accounts, should be issued by department and by activity categories. An analysis of the reports should be made by the responsible activity to identify significant variances and determine the reasons for them.

Functional status reporting is designed to provide management with the cost/schedule performance status of the program at the performing organization level. CWBS status reporting provides the same information associated with the elements which comprise the ship. By analyzing both the organizational and CWBS elements, the manager can assess the performance and progress of the crafts performing the work as well as the

different components of the ship. This two sided approach will reveal any problem areas on the ship as well as the responsible crafts. Monthly status reports at this level constitute the building blocks for status reports. Summing the status within a cost category will provide the performance status of that cost category in that account. Summarizing the performance of all cost categories to the hull level provides the basis for correlation of physical status on that hull. Analysis of indicated variances is accomplished by the shipyards progressing department, with the assistance of Production Control and the manufacturing crafts. Customer report requirements are satisfied from the same data base used for providing internal management reports. The accuracy of the information submitted from the responsible organizations and other sources is verified through the internal audits.

III. PERFORMANCE MEASUREMENT TECHNIQUES

In our opinion, there is no simple means of truely and accurately planning and managing a ship construction program. This has become an awesome task because of the nature and complexity of the program. High technology systems and economics have created a highly competitive market which demands lean pricing and ultimately a high degree of Program efficiency. The days of the fat budget margin have given way to finite Program Control and major customer involvement in performance evaluation. Although the Navy business approach may be to over-emphasize management control, we believe that its documented instructions can be utilized by the shipbuilder to some degree suitable to his operation for any ship construction program. Performance measurement techniques presented here when included in the analysis, with networks, physical progressing and milestone tracking, can identify not only potential cost and schedule problems but also the where, who, how and why of those problems early enough to take corrective action thus controlling major program impact.

Performance measurement is the feedback element which completes the control cycle. If the desired performance is being attained, the manager may allow operations to continue without change, and, if not, may institute corrective action to achieve the objectives. This vital feedback link is not an end in itself but is one part of a continuous process. The information obtained is used as an input for new and revised plans and then the process repeats itself.

Because a manager's time and ability to analyze data is limited, attention should be focused on key indicators and exceptions to favorable performance. The monitoring of key indicators helps managers keep tabs on operations and trends without having to sort through extraneous data. For each key indicator, a target or standard is created which when compared against actual performance shows progress (or lack of it) against a particular objective. A quick look at the indicators will reveal an up to date status for whatever is being monitored. By watching these indicators on a regular basis, problem areas can be identified and solved before they become endemic.

Targets or goals for key indicators used in the management of shipbuilding are predominantly based upon budgets and schedules that filter

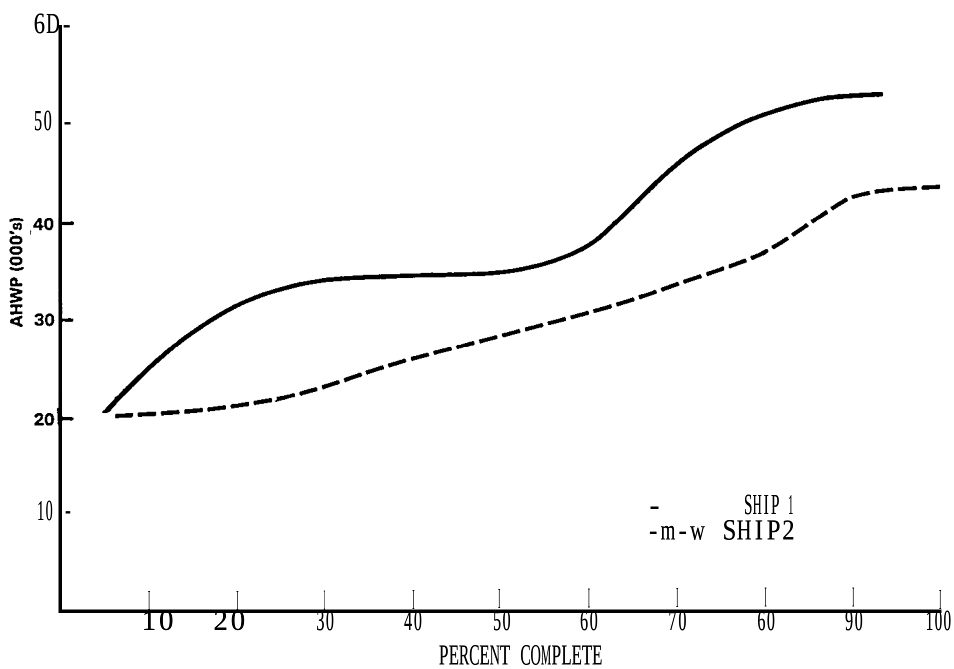
down from the contract baseline. Usually, once the contractually agreed upon dates are set and the number of production manhours negotiated, the manager need only to monitor the functional trades and/or CWBS elements for schedule progress and labor efficiency.

The following performance measurement products describe techniques which can be used to analyze cost and schedule data through the use of the CPR and other data sources. These are a selected few of many tools which may be generated from the data base for your use. In essence, these techniques can be used separately or in combination.

Actual Hours of Work Performed (AHWP) Per 1% Physical Progress

Discussion: This chart displays the average number of actual hours consumed per 1% physical progress. Significant increases in the average AHWP/1% physical progress could indicate adverse trends. This chart can be used for Estimate at Complete (EAC) projections by performing a simple mathmatical extension of past trends. This display is particularly helpful for establishing a baseline for follow ships. By plotting and comparing follow ship data against completed ship(s) or desired performance, effects of learning can be derived and forecasts can be made based upon prior similar ship performance.

ACTUAL HOURS OF WORK PERFORMED (AHWP)
PER 1% PHYSICAL PROGRESS

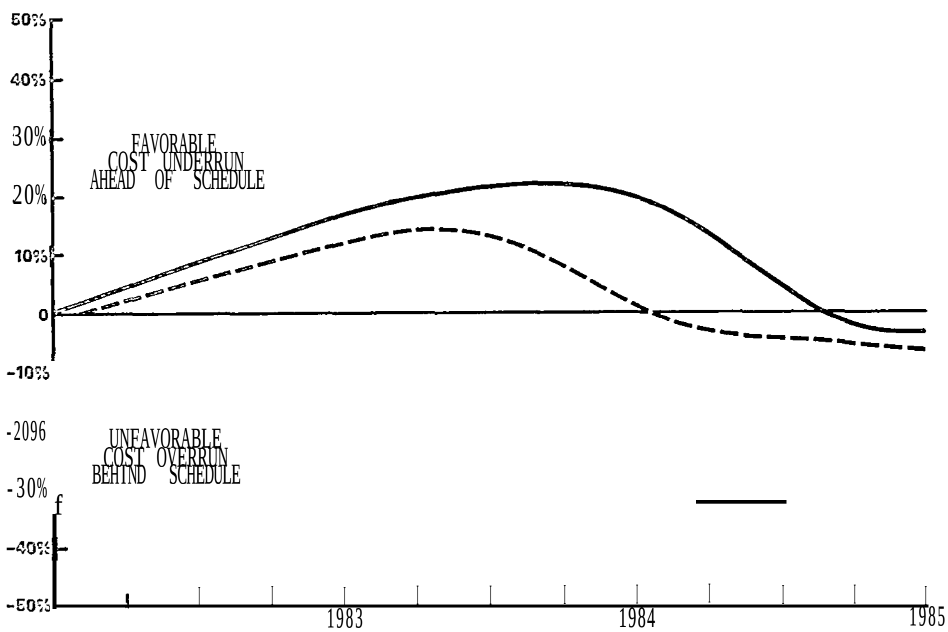


Derivation: The cumulative AHWP for vessel labor is divided by the percent complete to date to arrive at the AHWP per 1% physical progress as of the end of the particular reporting period.

Cumulative Schedule and Labor Variance Trend

Discussion: This chart displays cumulative schedule and cost variances for labor. This can be a very useful and quick tool for ascertaining a problem within an element or a craft. These variances can be plotted at any Work Breakdown Structure (WBS) or functional level and can be cumulative or monthly.

CUMULATIVE SCHEDULE AND LABOR VARIANCE TRENDS

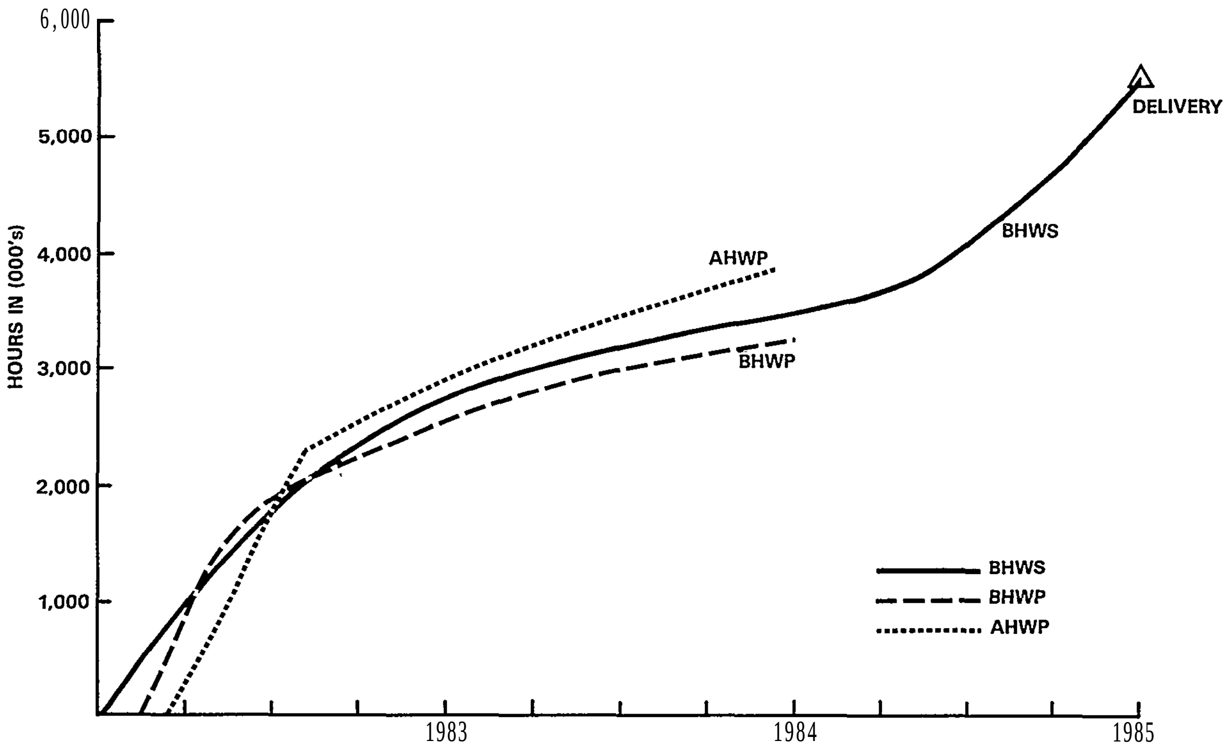


Derivation: The BHWS is the time-phased budget for all contract work. The BHWP is the sum of the budgets for all completed work plus the earned portion of the budget for in-process work. The AHWP is the actual hours charged to perform the work. The percent difference between the BHWS and BHBP and the AHWP and BHWP is the schedule variance and cost variance respectively.

Total Labor Plan

Discussion: This chart plots the time-phased Budgeted Hours of Work Scheduled (BHWS), Budgeted Hours of Work Performed (BHWP) and Actual Hours of Work Performed (AHWP) on a cumulative basis from the beginning of the contract. The curve depicted here is a more accurate representation and provides more information than the old conventional vessel labor curve used for Navy construction tracking for so many years. The Total Labor Plan reduces the number of assumptions and human error which existed in the development and calculation of the planned vs actual vessel labor curve. This chart illustrates the total production labor baseline and the current status of labor. The difference between the BHWS and the BHWP is the schedule variance and the difference between the AHWP and the BHWP is the cost variance. The essence of this graphical depiction is that both cost and schedule trends are shown together.

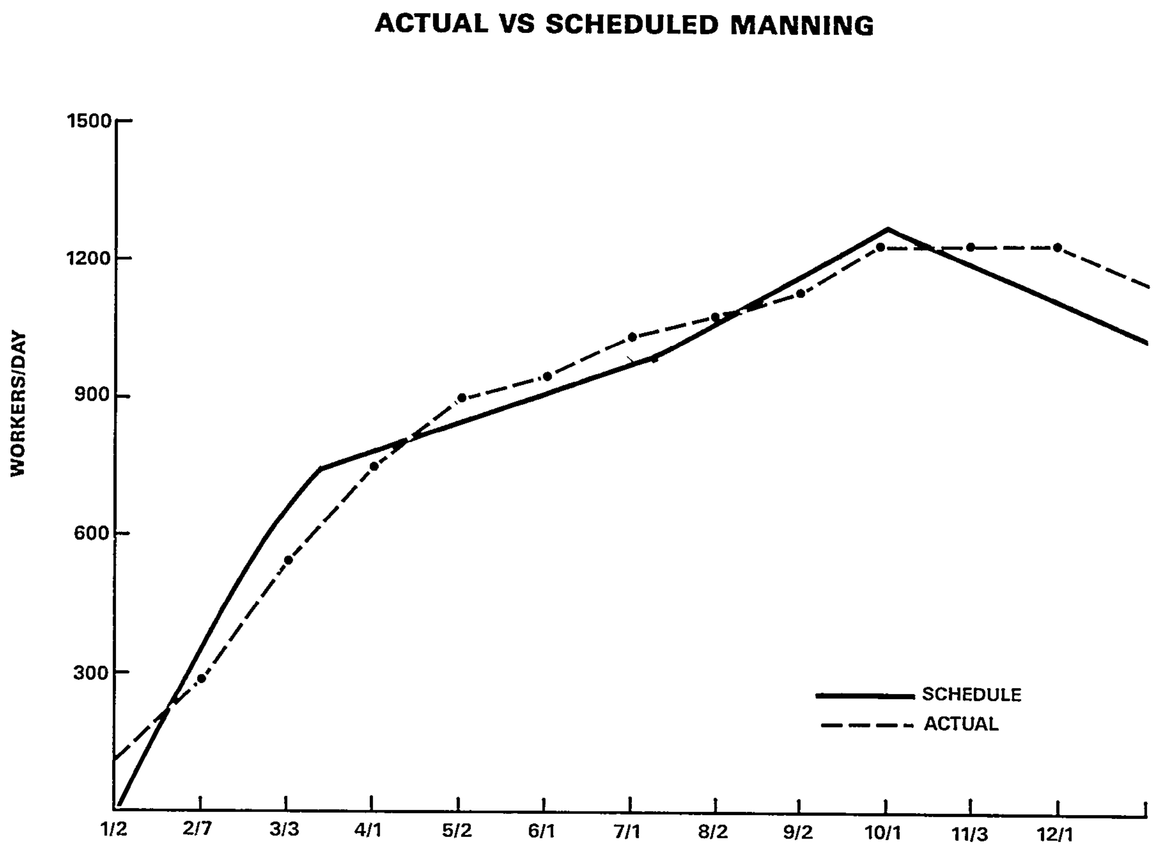
TOTAL LABOR PLAN



Derivation: The cumulative BHWS, BHWP and AHWP values are derived as described earlier. The difference between the cumulative BHWS and cumulative BHWP and the cumulative AHWP and cumulative BHWP is the cumulative schedule and cost variance respectively.

Actual VS. Scheduled Manning

Discussion: This graph gives the manager an indication of the probability of the shipyard performing all work as scheduled. It can also contribute towards analysis of schedule progress status. It does not give any indication of labor efficiency but does help to explain AHWP trends. The graph can be developed to display manning at any level, including trades, vessel or functional areas within the shipyard. This graph can also be used to validate or verify good planning or problem areas resulting from variances in manning number and craft mixes.



Derivation: The scheduled manning is taken from the shipyard manning schedule and the actual manning is extracted from time sheets, etc. and is plotted as it is expended.

Key Indicators Summary

Discussion: This chart displays monthly and cumulative performance ratings for cost and schedule. This chart is usually prepared for the Ship CWBS level and all of the supporting elements which comprise Ship as well as all of the trades performing the work. All of these indicators can also be graphed to give the manager a display of trends.

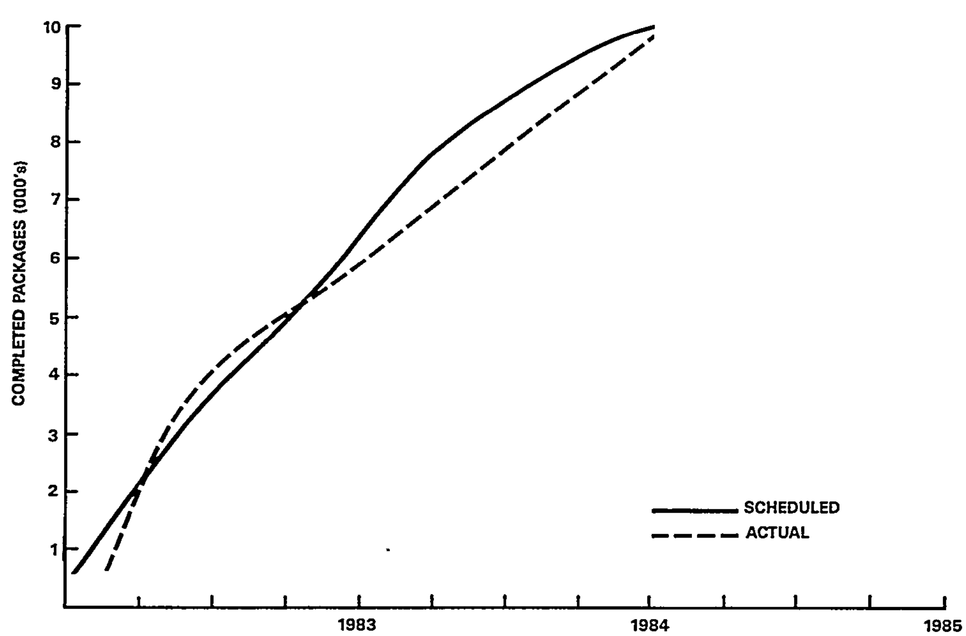
CWBS OR FUNCTIONAL ELEMENT	MONTHLY		CUMULATIVE		PERCENT COMPLETE			BAC (000s)		
	SPI	LPI	SPI	LPI	PLAN	PERF	SPENT	CUR	PREV	CHANGE
201.0 SHIP	1.04	.98	1.02	1.01	65.3	67.0	66.0	6,000	5,900	100

Derivation: The Schedule Performance Index (SPI) and Labor Performance Index (LPI) are performance indices computed by dividing the BHWP by BHWS for the SPI and BHWP by AHWP for the LPI. Percent completes are calculated by dividing the cumulative BHWS, BHWP and AHWP by the BAC. The BAC is the budgeted hours required to complete all work for the CWBS element or trade. These key indicators can also apply to total program costs by using BCWS, BCWP, and ACWP values.

Work Package Completes

Discussion: This graph provides another verification of schedule progress to the manager. By monitoring the work package completions, the manager can include this as part of his analysis towards the forecast of favorable or unfavorable future schedule performance as well as checking current trends.

WORK PACKAGE COMPLETES



Derivation: The scheduled complete dates for the work packages are part of the schedule developed when scoping work packages during the planning stage. Actuals are recorded as completed which are reported by the trade foreman or department.

Key Events Schedule

Discussion: This schedule sequentially displays all of the major events that occur throughout the construction of the ship. The monitoring of the completion of the Key Events is a very good indicator of schedule progress. Also, as follow ships are being constructed, their progress can be compared to the progress of previous ships at the same key event milestones.

EVENT NUMBER	DESCRIPTION	ACCOUNT NUMBER	DEPT.	SCHEDULE	ACTUAL (PREDICT)	COMMENTS
172	COMP INSTL AFT LOW MK-82 DIR.		24	2/11/83		
173	COMP INSTL FWD MK-82 DIR. (PORT)		24	2/11/83		
176	COMP ALL TANKS & VOIDS REQ. FOR F/O		85	2/18/83		
179	FLOAT-OFF		69	2/20/83		
167	LOS SPS-49 RADAR		35	2/21/83		
168	ST INSTL ELEX WARFARE SYS AN/SLQ-32		35	2/21/83		

DERIVATION: The identification of key events are governed by the type of ship and methods of the shipbuilder. The scheduled dates can be generated by the critical path networks developed during the planning and scheduling phases.

IV. CONCLUSION

The basic advantage of Performance Measurement is that it provides early warnings of areas that require improvement. These techniques provide management with information to assess strengths and weaknesses on a monthly basis and encourages better control of operating functions. Further, by using the summary level measurement techniques described, excellent progress information is available to keep abreast of the cost, schedule, and technical performance as well as estimates at complete. Managers then can make the right adjustments to operations to assure that the production objectives and goals will be achieved. Without adequate and timely performance measurement, construction progress can deteriorate quickly and cause planned schedules and budgets to become obsolete.

BUILD STRATEGY DEVELOPMENT

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ABSTRACT

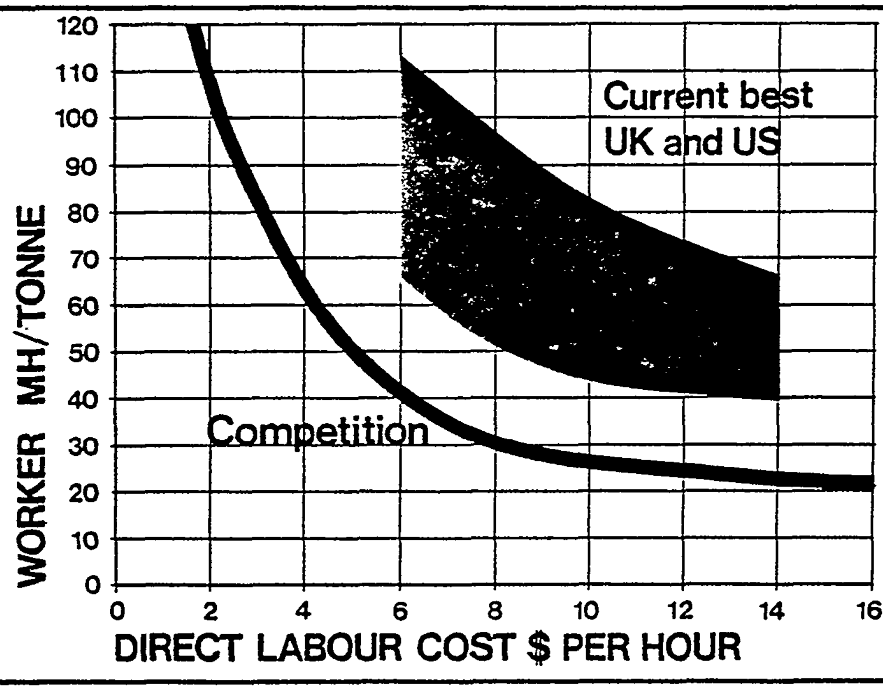
All shipbuilders are searching for ways to improve productivity. The emphasis must be on those ways of achieving productivity improvement which are cost effective and also improve profitability.

The paper looks at factors that impact productivity and concludes that the key is the ability to organise work such that facility utilisation and labour utilisation are optimised.

The reasons for the success of the traditional method of ship production and the reasons for the development of, and the concepts of, the modern approach to ship production are outlined.

The objectives and elements of a company shipbuilding strategy are described. Finally, the need to formally develop a build strategy for each vessel and the typical contents of build strategy documentation are described.

THE PRODUCTIVITY GAP



The Productivity Gap

Labour cost is only one element of total ship cost, but it is possibly the element which is most under the control of shipyard management.

For the same vessel type and size, Japanese and certain Scandinavian yards will use only one third to one half of the hours and take less than half the time to construct the vessel as compared to many yards in the United States and parts of Europe.

The Competitor Curve

The curve drawn opposite is a line of constant low cost per tonne. Countries on the line include:

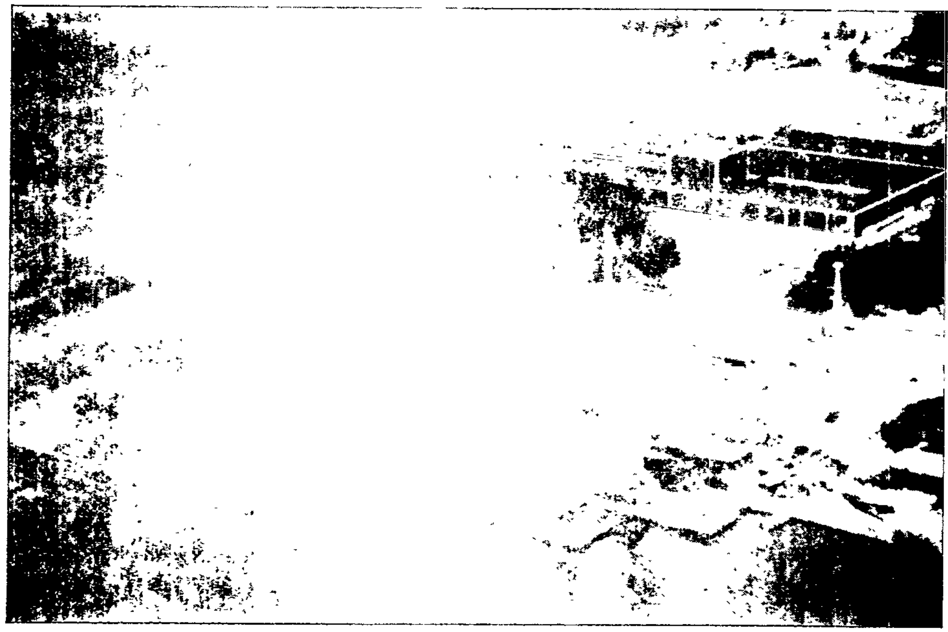
South Korea with low labour cost and currently poor productivity.

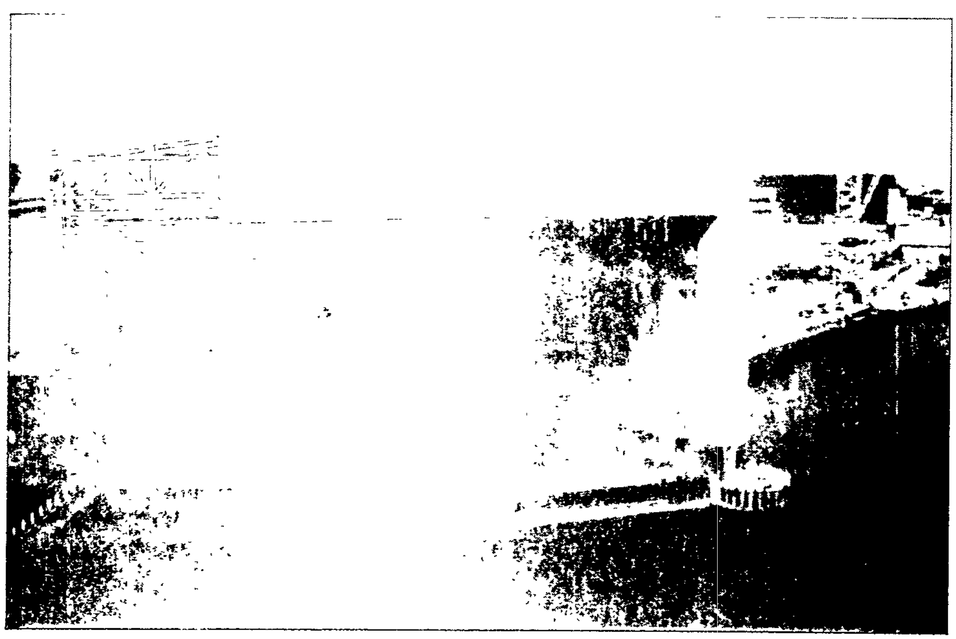
Japan with labour costs similar to those in the UK and good productivity.

Sweden and Denmark with high labour costs and in some cases the best productivity.

Other countries lie above the line, ie, there is a productivity gap. Unit labour costs will not fall. The only way of moving towards the competitor curve is to improve productivity.

The Japanese and Koreans are not standing still - they are working to open the gap.





Factors Which Impact Productivity

In which direction should mangement attention be focussed in order to improve labour productivity? Let us consider:

Facilities
Planning and Control Systems
Trade Unions.

Facilities

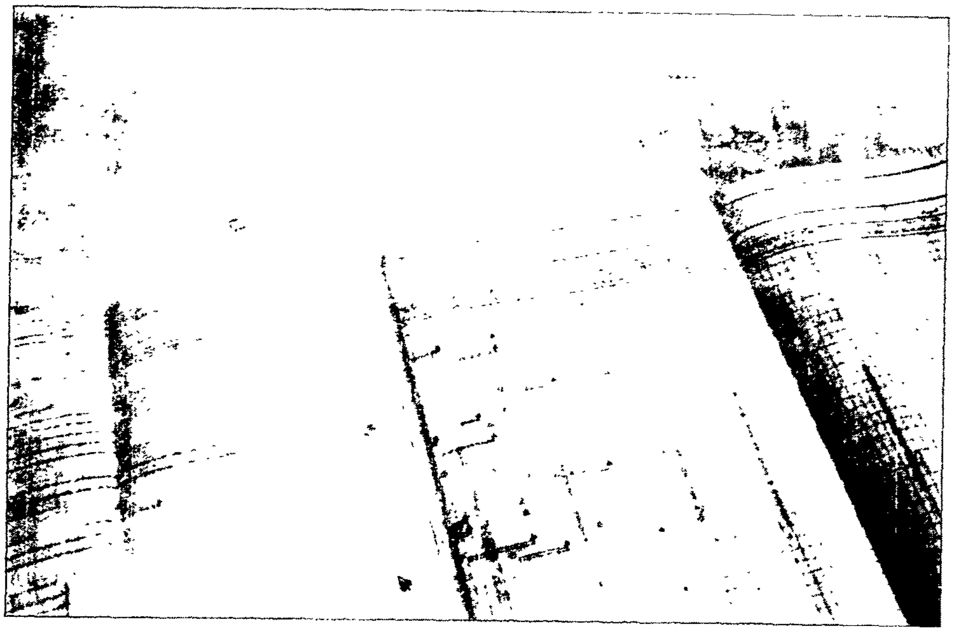
Can capital investment lead to improved productivity? Consider the situation around the world:

Japanese and Scandinavian yards have made huge investments in facilities and are amongst the most efficient world shipbuilders.

The Koreans have also invested heavily, but Korean yards are not top of the productivity league.

Significant capital has been invested in the UK. Those yards which have the best facilities are among the most efficient in the UK, but are well behind the best in the world.

Good facilities are an element in the productivity equation. However, it is not possible to become efficient by capital investment alone.



Planning and Control Systems

Can the implemenation of sophisticated computer systems lead to improved productivity?

In Japan, investment in computer systems has not been as great as elsewhere in the world.

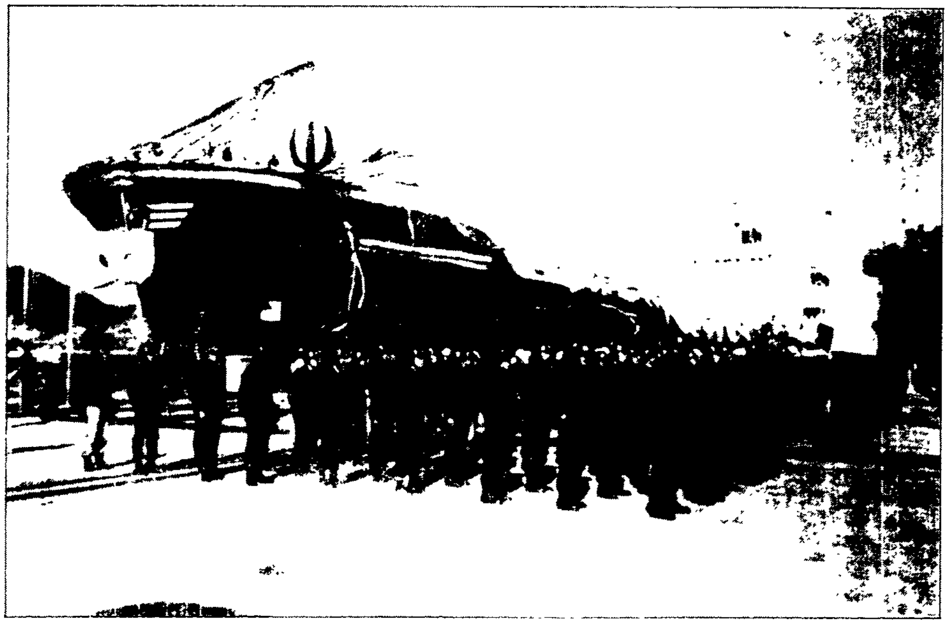
Planning systems are simple and effective, and Japanese shipbuilders have initially concentrated on computerised material control systems.

European and US yards lead the Japanese in the implementation of CAD/CAM systems.

The Koreans have purchased and implemented sophisticated computer based manufacturing control systems but, as previously mentioned, they are nowhere near the top of the productivity table.

In the UK and elsewhere, many yards have made a substantial investment in both facilities and systems but still do not figure near the top of the productivity table.

As with facilities, implementation of systems will not necessarily lead to a breakthrough in labour productivity.



Ability to organise work, such that facility utilisation and labour utilisation are optimised.

Unions and Trade Demarcation

In many countries, it is believed by management that Union obstruction and lack of trade flexibility are major factors in holding back productivity improvement:

> In the Far East, the labour force is not as regimented as is widely believed in the West. Even in Japan, there are demarcation restrictions.
>
> In Scandinavia, the Unions are strong, but work with management.
>
> In the UK, flexibility agreements have been negotiated. However, management has not taken full advantage of them.

Trade union attitudes and demarcation issues may provide management with problems but given good communications they need not be a barrier to improved productivity.

What is the Key to Improving Productivity?

If investment in sophisticated facilities and systems will not guarantee productivity improvement and trade unions are not a barrier, what avenues are open to management? What is the key?

The key is the ability to organise work, such that facility utilisation and labour utilisation are optimised.

HOW TO IMPROVE WORK ORGANISATION

- STANDARDISATION
- SIMPLIFICATION
- SPECIALISATION

THE FUNDAMENTAL RULE OF MASS PRODUCTION

'The same personnel, working in the same workplaces, make repeated operations to produce large numbers of cheaper products'.

K. Yacota and T. Kuriyama

Work Organisation

How do you improve work organisation? In simple terms, the objective is to STANDARDISE, SIMPLIFY and SPECIALISE.

Increased STANDARDISATION will lead to the identification of a limited range of interim products.

SIMPLIFICATION of interim products will lead to reduced work content and easier production.

This in turn will .allow SPECIALISATION through the establishment of workstations, each producing a limited variety of products with purpose-designed processes and equipment.

Mass Production

It is possible to approach a mass production situation in shipbuilding - even with "one-offs". Standardisation and simplification lead to the identification of large numbers of . . similar interim products which can be passed through clearly defined workstations. A workstation implies the same personnel, working in the same workplace, making repeated operations.

GOOD WORK ORGANISATION

High utilisation of working areas
Clearly identified interim products
Clearly identified workstations
Identified and packaged materials
Relevant technical information
Simple but effective planning systems
Good housekeeping

HIGHLY PRODUCTIVE YARDS ARE CHARACTERISED BY

- Clearly defined objectives and policy
- Short build cycles
- Overlapping of steel and outfit work
- Management attention to factors like tons/m^2/shift/month

Work Organisation Characteristics

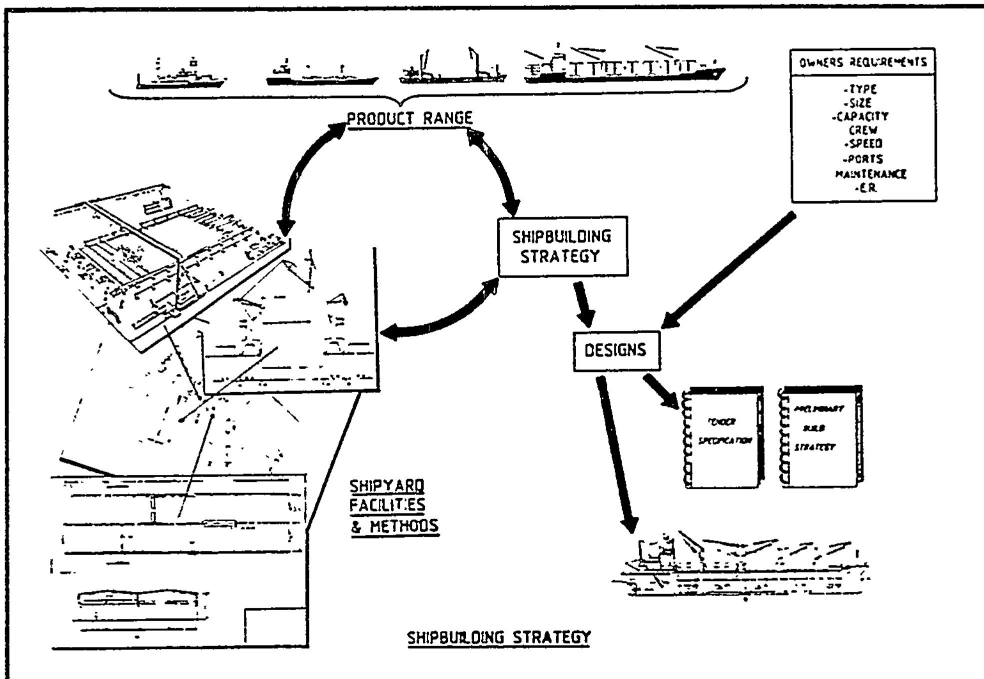
Good work organisation is manifested in the shipyard by the following:

- high utilisation of working areas
- clearly identified interim products
- clearly identified workstations
- clearly identified and packaged materials
- provision of relevant technical information
- simple but effective planning systems
- good housekeeping.

Characteristics of Productive Yards

Productive and well organised yards have clearly defined objectives and policy which provide a consistent framework for all company activities. They have a shipbuilding strategy.

The overlapping and de-coupling of steel and outfit enables reduced cycle times to be achieved. Furthermore, it provides flexibility in manufacturing. The achievement of short build cycles creates the pressure for further standardisation, simplification and specialisation.



BASIC OBJECTIVES

Competitive in total cost
Competitive in project duration
Maintain delivery dates
Efficiently build "one-offs"
Be profitable

Shipbuilding Strategy

A shipbuilding strategy is a statement of company policy. It is a statement of shipbuilding objectives. It is the definition of the ideal or optimum organisation and build method within the framework of the company's shipbuilding ambitions.

Many companies need to develop a new strategy, either because they do not exhibit the characteristics of good work organisation or the characteristics of the highly productive yards and/or they are losing their competitive edge.

In the UK, we have to go all the way because we have to be internationally competitive. We have to change until we have all the characteristics of the "modern method" of ship production, and more.

In the United States, the basic objectives are, with some exceptions, not concerned with international competitiveness. They would, however, include:-

a) to be competitive (nationally) in terms of total cost.

b) to be competitive (nationally) in terms of project duration.

c) to maintain strict adherence to delivery dates.

d) to be capable of efficiently building "one-offs" in a poor market situation.

e) to be profitable.

Before examining some of the elements of the new shipbuilding strategy, it is appropriate to look back in time in order to understand the need for a new approach.

THE TRADITIONAL METHOD OF SHIPBUILDING

A Look Back in Time

The transition from wooden to iron and eventually steel ships was made successfully, despite the fact that the materials had very different characteristics. This can probably be attributed to the fact that although the materials changed, the basic construction strategy did not.

This early method of construction simply consisted of the erection and joining of parts to form a complete object, in this case the ship. On examination, the traditional method can be seen to be founded on a number of basic concepts which appear central to its successful development:

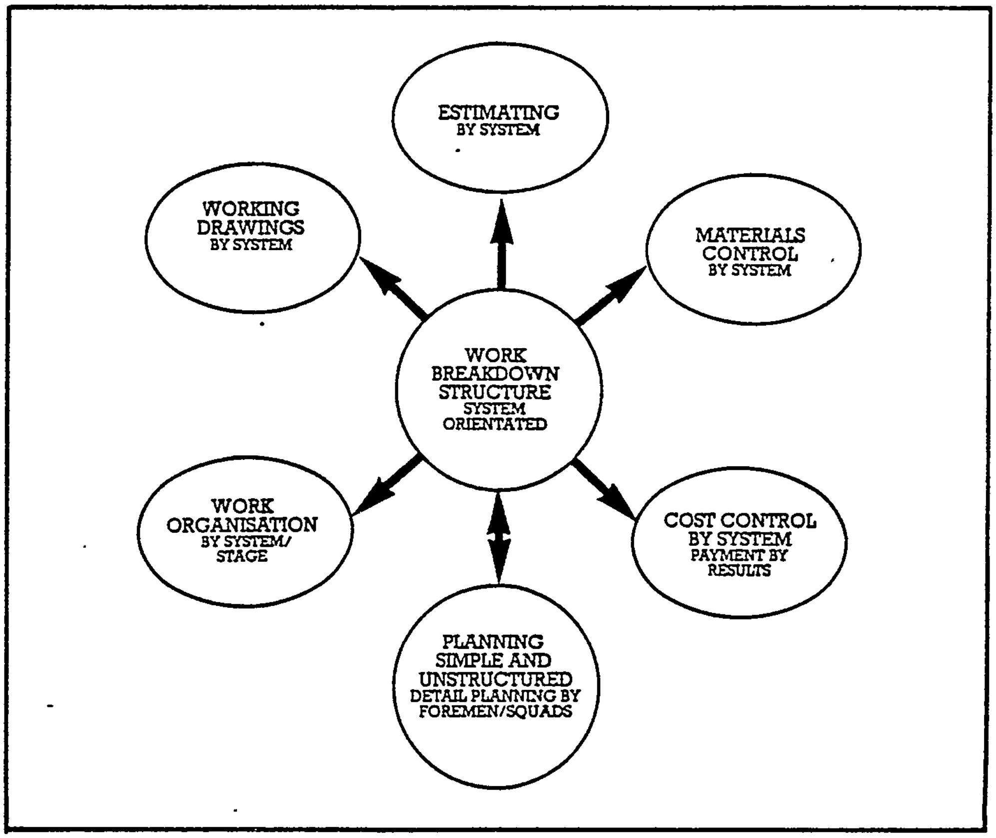
1) The use of a consistent work breakdown structure. This was system orientated in both steel (structural systems, eg, frames, shell plating, etc) and outfit.

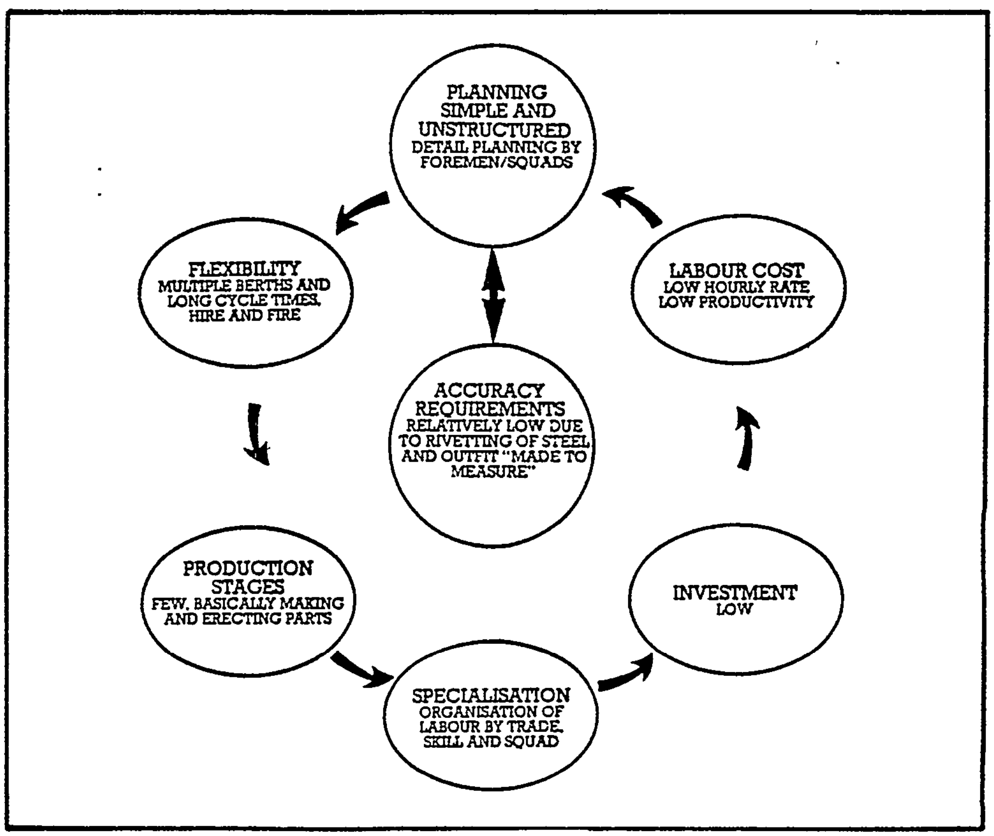
2) - Efficient organisation of work through the development of specialist squads. Each squad had clearly defined responsibilities in terms of system(s) and work stage(s).

3) Complete conformity of technical information with production methods. Design and mould loft information was system orientated for both steel and outfit.

4) System orientated estimating, materials control and cost control. This gave a relatively straightforward task in comparing actual with estimated costs for labour and materials.

5) The use of simple and unstructured planning and control systems. Detailed planning was left very much to first line management. Control was essentially by system and trade group, with perhaps a shop/ship breakdown. The use of payment-by-results systems motivated workers to plan ahead to ensure satisfactory flows of information and materials, thus releasing management from much of its detail planning responsibilities.


ESTIMATING
BY SYSTEM
WORKING
DRAWINGS
BY SYSTEM
MATERIALS
CONTROL
BY SYSTEM
WORK
BREAKDOWN
STRUCTURE
SYSTEM
ORIENTATED
WORK
ORGANISATION
BY SYSTEM/
STAGE
COST CONTROL
BY SYSTEM
PAYMENT BY
RESULTS
PLANNING
SIMPLE AND
UNSTRUCTURED
DETAIL PLANNING BY
FOREMEN/SQUADS


PLANNING
SIMPLE AND
UNSTRUCTURED
DETAIL PLANNING BY
FOREMEN/SQUADS
FLEXIBILITY
MULTIPLE BERTHS AND
LONG CYCLE TIMES.
HIRE AND FIRE
LABOUR COST
LOW HOURLY RATE
LOW PRODUCTIVITY
ACCURACY
REQUIREMENTS
RELATIVELY LOW DUE
TO RIVETTING OF STEEL
AND OUTFIT "MADE TO
MEASURE"
PRODUCTION
STAGES
FEW. BASICALLY MAKING
AND ERECTING PARTS
INVESTMENT
LOW
SPECIALISATION
ORGANISATION OF
LABOUR BY TRADE.
SKILL AND SQUAD

6) Flexibility. The use of multiple berths and long cycle times gave squads a degree of flexibility within which they could organise their work. Also labour was shed as and when necessary to match the workload.

7) Clearly defined and unambiguous production stages. Basically, these were the marking/templating, making, erecting, fairing and joining of steel hull parts and the lining off, drawing/templating, making and installation of outfit parts.

8) Specialisation. Labour was organised by trade and skill level. Work was organised around key squads which allowed management to develop simple indicators with which to plan and monitor production in overall terms.

9) Low investment, low hourly wage rates and low productivity.

10) Relatively low accuracy requirements. This was due to the inbuilt flexibility of the primary joining method used, ie, rivetting. Time to complete construction -work could be determined with a high degree of probability since process time was less likely to be affected by small dimensional inaccuracies. Control was also exercised by the payment systems - spoilt work, no pay.

The way in which the various aspects of the Traditional Ship Construction Method interface is shown opposite.

THE NEED FOR
A NEW APPROACH

THE REQUIREMENTS OF
WELDING AND ASSEMBLY METHODS

New way of providing flexibility
New work breakdown structure
New basis for planning and monitoring
New way of preparing information

The Need for a New Approach

The initial impact of the introduction of welding and assembly methods to shipbuilding included the following:

The effect of thermal distortion on dimensional accuracy.

The introduction of new production stages, eg, subassembly and unit assembly.

The breaking up of the previous continuity of responsibility from collection of material through to erection.

During the early stages of this development process, there was little impact on outfitting which continued to be done in the traditional manner. The need for changes in the organisation of shipbuilding activities had, however, arrived.

In the late 1950s/early 196Os, a chain of events led to a completely new approach to ship production. The primary motivating force was the rapidly increasing ship size, supplemented by the desire to build larger units in order to reduce work done at the erection stage. The high cost of new slipways and building docks with large capacity cranes provided the requirement for dramatically reducing the number of such facilities and correspondingly the length of the erection cycle times. These developments had the following impact:

There was a need to find ways of providing flexibility in production areas since the flexibility previously available through long erection periods and simultaneous construction was lost.

There was a need for a new work breakdown structure since ships were no longer built system by system.

There was a need to establish a new basis for planning and monitoring production activities.

There was a need to reorganise the way in which manufacturing information was prepared.

These needs are satisfied by the "modern method of ship production" referred to later.

REQUIREMENTS TO SATISFY SHIPBUILDING OBJECTIVES

Project duration
Adherence to delivery dates
Capability of building "one-offs"

PROJECT DURATION

Design rationalisation and standardisation
Overlapping and de-coupling of steel and outfit activities
Hull subdivision to minimise cycle time
Maximisation of outfit assembly work

Other Requirements to Satisfy Shipbuilding Objectives

The shipbuilding objectives referred to earlier are also an important input to the development of the shipbuilding strategy. Consider three of these objectives:

- to be competitive in project duration
- to maintain delivery dates
- to be capable of efficiently building "one-offs".

Project Duration

To shorten the project duration, it is necessary to reduce both preproduction and production cycle times:

> The reduction of preproduction time may be achieved through a policy of design rationalisation and standardisation so that drawings and specifications can be completed earlier.
>
> Production cycle time may be reduced by carrying out as many production activities in parallel as possible.
>
> This means not only overlapping and de-coupling of steelworking and outfitting activities but also subdividing the vessel to minimise erection cycle time by reducing the number of erection units and providing as many erection faces as early as possible.
>
> This philosophy must then be applied to the units themselves and to subunits and subassemblies. Outfitting must be approached in the same way with the maximisation of outfit assembly work to reduce installation time.
>
> Modern shipbuilding is very much a matter of efficiently organising the assembly processes.

DELIVERY DATES

Effective material control
Good dimensional accuracy
Stable production system
Consistent planning and control data

"ONE-OFFS"

Rigorous design rationalisation/
standardisation
Application of group technology
Formation of interim product families
Simulation of series effect

Delivery Dates

Strict adherence to delivery dates in parallel with short production cycle times requires effective materials control and uniform levels of good dimensional accuracy.

Without these ingredients, schedules cannot be drawn up with the necessary confidence levels.

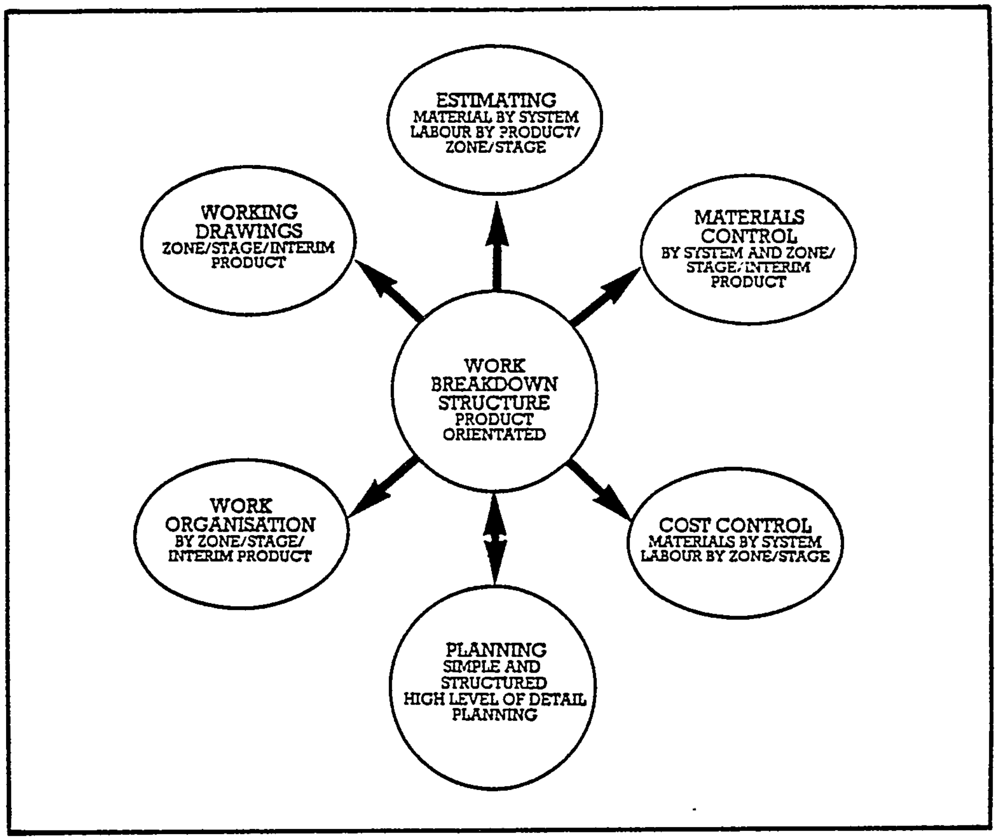
The development of consistent planning and control data requires a stable production system where similar tasks are undertaken by the same work groups, in the same work areas, using the same methods and equipment.

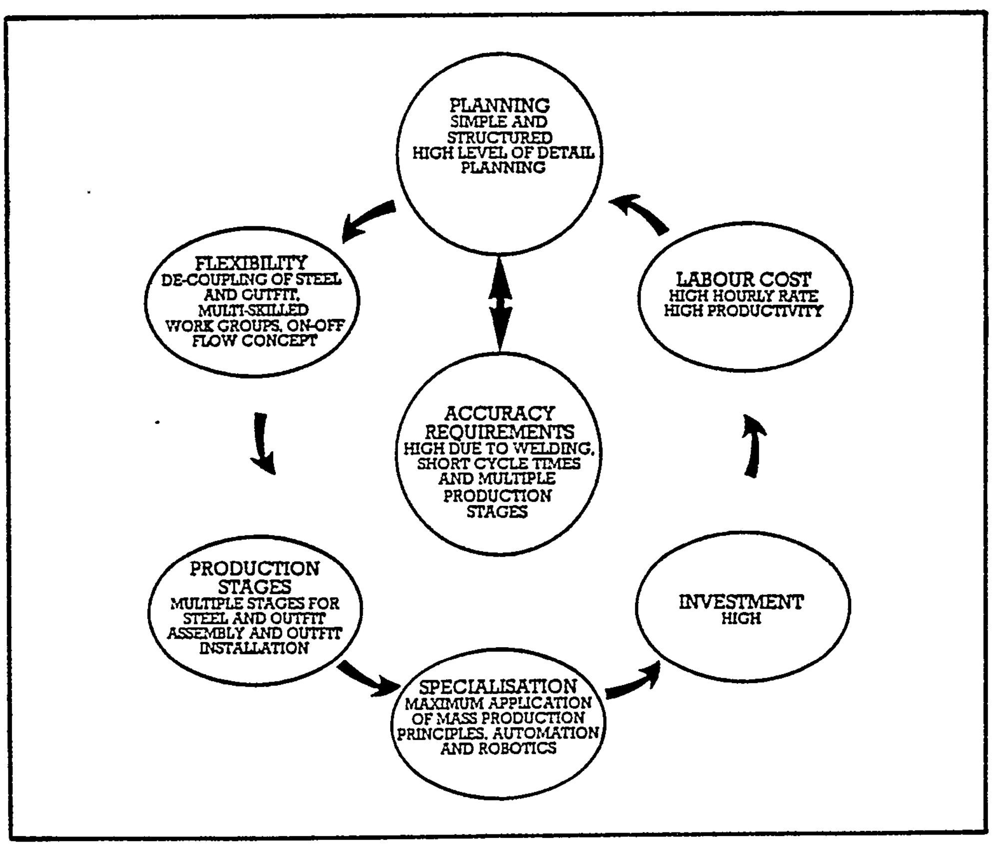
"One-Offs"

Many leading shipbuilders are achieving high levels of productivity whilst building what appears to be a wide range of ship types and sizes:

This has been achieved by rigorous programmes of design rationalisation and standardisation and related organisation of work in order to simulate the series effect.

This, in turn, is achieved by the application of group technology and a product subdivision which leads to the formation of interim product families. The work content and sequence of operations of each member of a specific family are contrived to be approximately the same.


ESTIMATING
MATERIAL BY SYSTEM
LABOUR BY PRODUCT/
ZONE/STAGE
WORKING
DRAWINGS
ZONE/STAGE/INTERIM
PRODUCT
MATERIALS
CONTROL
BY SYSTEM AND ZONE/
STAGE/INTERIM
PRODUCT
WORK
BREAKDOWN
STRUCTURE
PRODUCT
ORIENTATED
WORK
ORGANISATION
BY ZONE/STAGE/
INTERIM PRODUCT
COST CONTROL
MATERIALS BY SYSTEM
LABOUR BY ZONE/STAGE
PLANNING
SIMPLE AND
STRUCTURED
HIGH LEVEL OF DETAIL
PLANNING


PLANNING
SIMPLE AND
STRUCTURED
HIGH LEVEL OF DETAIL
PLANNING
FLEXIBILITY
DE-COUPLING OF STEEL
AND OUTFIT.
MULTI-SKILLED
WORK GROUPS. ON-OFF
FLOW CONCEPT
LABOUR COST
HIGH HOURLY RATE
HIGH PRODUCTIVITY
ACCURACY
REQUIREMENTS
HIGH DUE TO WELDING,
SHORT CYCLE TIMES
AND MULTIPLE
PRODUCTION
STAGES
PRODUCTION
STAGES
MULTIPLE STAGES FOR
STEEL AND OUTFIT
ASSEMBLY AND OUTFIT
INSTALLATION
INVESTMENT
HIGH
SPECIALISATION
MAXIMUM APPLICATION
OF MASS PRODUCTION
PRINCIPLES. AUTOMATION
AND ROBOTICS

Shipbuilding Strategy

Each company's shipbuilding strategy will, of course, be unique. It will be shaped according to particular shipbuilding ambitions and objectives with regard to product range, rate of output, facility development, organisation, build method and so on. However, the strategy must lead to a construction method and organisation which exhibits the characteristics of the "modern method of ship production" shown opposite. This is the way to achieve productivity improvement which is cost effective and which will increase the opportunity to improve profitability.

Note especially:

The work breakdown structure is product orientated. The final product, the ship, is subdivided into a hierarchy of interim products which are progressively joined together, stage by stage, to make the finished product.

Work organisation, working drawings and materials control are correspondingly based on the same interim product hierarchy.

Estimating and cost control are product orientated for labour and system orientated for materials.

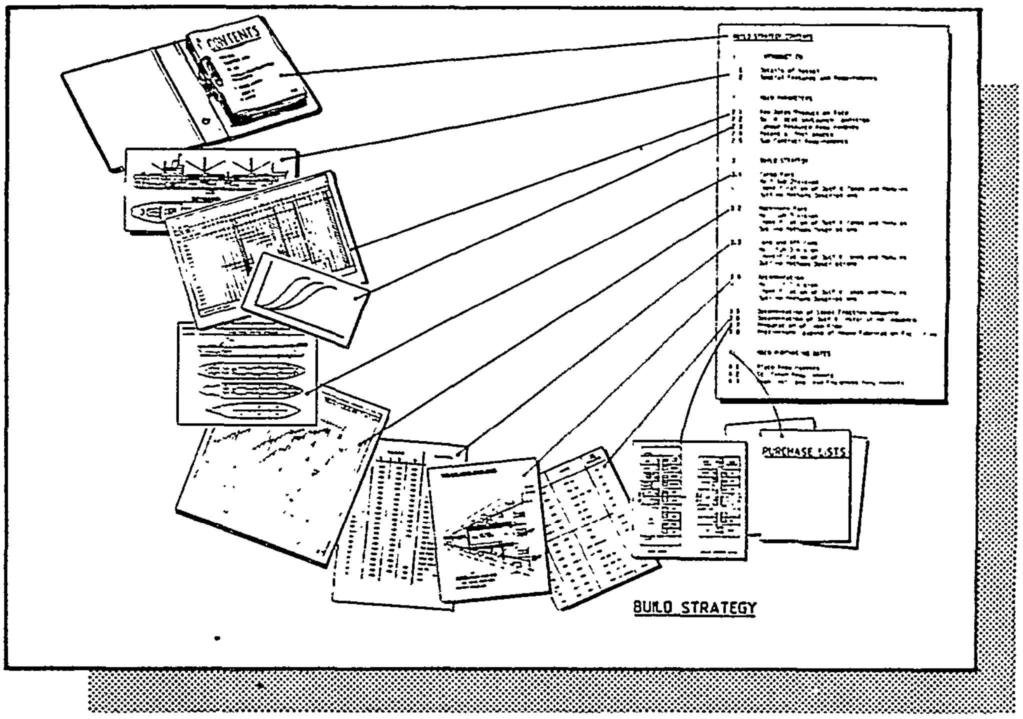
Planning is simple and structured. Control is by planning unit/department at the higher level and by work package/work station at the detail level. There is a high level of detail planning.

Flexibility is achieved by de-coupling of steel and outfit, by the use of multi-skilled work groups and by the on-flow/off-flow work concept.

There are a relatively large number of production stages and a high level of specialisation at purpose-designed workstations.

There is relatively high investment, high hourly wage rates and high productivity.

Accuracy requirements are high, with many changes in responsibility between stages. Control is exercised by the workers and foremen at each stage.


CONTENTS
PURCHASE LISTS
BUILD STRATEGY

Build Strategy

Each new or potential ship contract received by the shipyard requires the formulation of a build strategy. The build strategy is the application of the shipbuilding strategy to a particular contract. It may be drawn up formally or informally. Where a shipyard has been working to a relatively uniform construction method over a period of years9 much of the work to be done in completing the build strategy would be produced quickly with most attention being given to those areas identified as being unusual.

However, in the climate of change now being experienced, a structured and documented approach is recommended. The objectives of formally developing a build strategy for each vessel include:

- To provide a process for ensuring that design development takes full account of production requirements.

- To systematically introduce production engineering principles that reduce vessel cost, work content and cycle time.

- To identify interim products and to create a product-orientated approach to engineering and planning of the vessel.

- To determine resource requirements and overall facility loading.

- To create parameters for programming and detail planning of engineering, procurement and production activities.

The formal preparation of the build strategy ensures that all significant features of the contract are considered early enough for problem areas and bottlenecks to be identified and effectively overcome. The distribution of the document ensures communication of key decisions throughout the shipyard and ensures that everyone is working to a common plan.

The build strategy becomes the basis for all decision-making related to the timely completion of the contract from basic design through production to commissioning and delivery.

BUILD STRATEGY DOCUMENT

Vessel characteristics
Production parameters
Strategy – hull
Strategy – machinery spaces
Strategy – accommodation
Planning framework
Purchasing dates

BUILD STRATEGY

A means of planning for change from contract to contract within the framework of the shipbuilding strategy.

The Build Strategy Document

Typical contents would include the following:

- Vessel Characteristics
  - details of vessel
  - special features/requirements
- Main Production 'Parameters
  - key dates/planned production rate
  - build location/launch condition
  - labour resource requirements
  - potential bottlenecks
  - subcontract requirements
- Build Strategy - Hull
  - hull subdivision
  - erection sequence
  - method descriptions
- Build Strategy - Machinery Spaces
  - installation zones
  - installation sequence
  - identification of outfit assemblies
  - method descriptions
- Build Strategy - Accommodation
  - structure subdivision
  - erection sequence
  - installation zones and sequence
- Planning Framework
  - 1ist of planning units
  - type plan
  - interim product groups and workstations
  - workstation load analyses
  - productivity targets
- Main Purchasing Dates
  - steel plate and section requirements
  - high cost/long lead time equipment and materials.

A formal approach to build strategy (and the production of build strategy documentation) provides a means of planning for change from contract to contract within the framework of the shipbuilding strategy.

A CONCEPTUAL (DATA BASE DESIGN) INFORMATION MODEL FOR OUTFIT PLANNING

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Richard L Diesslin has nearly 10 years of experience in structured analysis and conceptual modeling, industrial management, group technology, and the development of computer aids and simulation tools for production planning, evaluation, and scheduling. He is presently involved with the state-of-art review to define the "to-be" architecture for the aerospace factory of the future (ICAM 1105). Previous ICAM work includes structured analysis models for the Air Force Integrated Planning System (IPS), the Integrated Center (ICENT), and Manufacturing Control-Materials Management (MC-MM). He has also contributed to a technoeconomic feasibility study of numerical control (NC) machining applied to complex models, and has provided technical and financial management consulting to firms affected by foreign imports.

ABSTRACT

This paper provides a summary of the conceptual data base design developed in the NSRP report entitled "A Conceptual Information Model (Data Base Design) For Outfit Planning." This study was performed using conceptual function and information modeling techniques in order to provide an in-depth understanding of the outfit planning systems specifications. This analysis will be useful to shipbuilders considering developing/buying a manufacturing information system in terms of how to diagnose systems specifications and how well a system will integrate with other existing systems as well as specifically illustrating the elements necessary in an outfit planning based manufacturing approach.

A CONCEPTUAL (DATA BASE DESIGN) INFORMATION MODEL FOR OUTFIT PLANNING

This paper describes a high level data base design which supports outfit planning. It was crucial to gain a holistic understanding of the shipbuilding industry and then to define outfit planning in more detail before establishing the information requirements necessary for maximum control of outfit planning activities. The following sections are laid out especially to highlight the definition of data base management (Section 1). Section 2 then relates what steps are involved in developing a conceptual design of a data base management system. Finally, Sections 3 and 4 explain the actual high level data base model and the recommendations on how to use it, respectively.

SECTION 1 - DEFINITION

A data base is essentially a group of "storage bins" for information which resides in a computer. The data base design is highly dependent on what the company desires to use the information for. In other words, the way in which the storage bins are defined (data base design) makes it easy or difficult to locate or retrieve the pieces of information desired, depending on the way in which the information will be searched for. Carrying the storage bin analogy further, assume in a warehouse that storage bins have been defined for parts based on their shape. All round parts would be in one bin, all square ones in another, etc. Clearly, this would be a very useful design if parts were always searched for by what shape they were; however, if the part number were used to search for a part, it would be very difficult to find the proper storage bin for that part, and hence, shape would be a poor design concept. The same is true with information. Information can be categorized in many ways, but the task of designing a good data base is to try to arrange data depending on the way it is going to be used.

A more formal definition reads:

> "A data base is a collection of operational data [information] used by the application systems of some particular enterprise."[1]

Application systems are essentially the software programs and report generators used by a company. Operational data is any relevant information having to do with running the business. In the model developed in this paper the application system(s) is outfit planning and the enterprise is a U.S. shipyard. It is important to think of operational data in terms of relationships or associations between certain basic entities.[1] An entity is anything about which there is a need to collect/record information on. To illustrate this for a part type, relevant information might be part number, part name, color, and weight; for an employer it could be social security number, name, and job description; for a project it could be the project number, customer name, and project description--part, person, and project, therefore, are all information entities. The aspects that describe the entities are called attributes. The next section will attempt to develop these concepts further.

SECTION 2 - DEVELOPMENT OF A CONCEPTUAL DATA BASE DESIGN

The overall design development cycle, Figure 1, provides a logical sequence in information gathering and organization in order to produce quality results effectively and efficiently. Since conceptual or high level design is the cornerstone of an overall detailed design, it is important to use techniques which can be used at a high level as well as a very detailed level. Conceptual modeling techniques have gained wide acceptance in the last 10 years for these purposes, and many modeling methods have evolved. The conceptual modeling technique used in this project[3] is elaborated on in this section as the design steps in Figure 1 are discussed.

The first step is information collection. Information collection techniques are fairly standard in most conceptual modeling methods. Information is usually gathered by a variety of methods including literature searches, surveys, interviews, comparison to similar systems, etc., and the methods are usually used in combination, as was done for outfit planning in this project.

The next step is information organization. Organizing information properly is a crucial process in the development of a conceptual design and it is important that the graphic technique used can adequately group information into useful categories. The whole idea behind graphic conceptual modeling is to enhance creativity and clarity by going beyond the semantic problems normally associated with written textual descriptions. In fact, creativity is enhanced because graphic modeling techniques are being used as an organization tool and

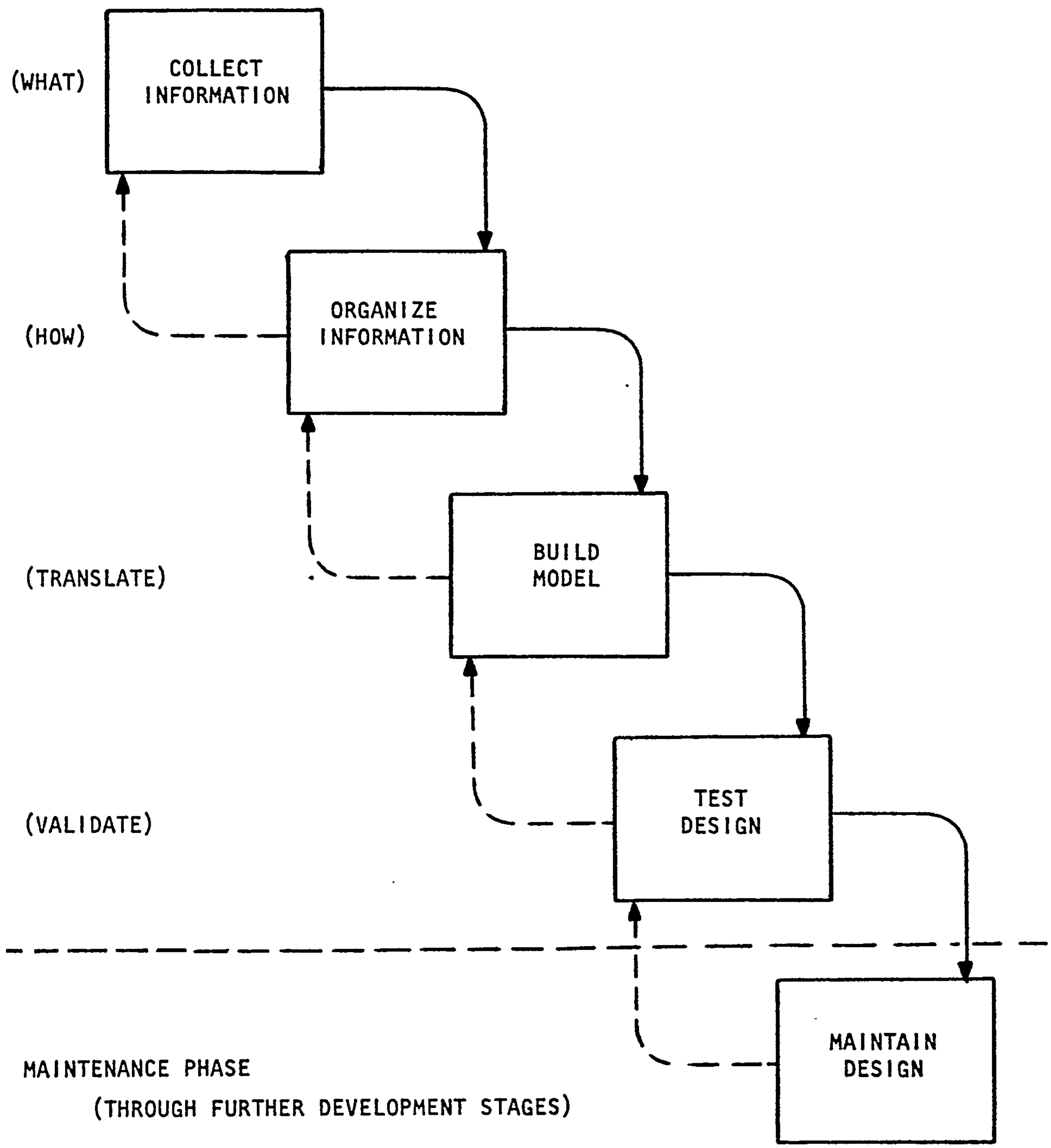


Figure 1. Design development cycle.[2]

system (data base) definition is more accurate because the analysis can focus on the pieces before, after, or while they are brought together into a whole system concept.

Using thorough information organization techniques such as textual analysis methods and targeted graphic modeling, the next phase involves actually interpreting this information to create the high level conceptual data base design. It consists of bringing the individual pieces together to develop a whole system structure. The holistic configuration of the data base will be more than the sum of its parts due to the multifaceted nature of information relationships. This is why in actual practice a designer may start by trying to describe the whole system first, then develop individual parts of the model in more detail, and finally, return to the whole system model and expand it further. It is certainly an iterative process which the conceptual modeling techniques greatly enhances. Without the clarity of such models, development would be quickly bogged down in long textual discussions, making modification difficult and possibly hiding foggy reasoning.

Extensive model testing is important to reduce problems later, in the implementation phases of the data base design. A model must be practical in the sense that it does not make incorrect assumptions (i.e., relating things that do not actually exist) or incorporate untested ideas. At the same time, it must be flexible so that it is not restricted only to the current operating structures or technologies. This holistic systems analysis should favor a thorough systems definition, but expert review and direction are necessary to assure a non-bias, conceptual model. Actual test cases can be used as a sort of simulation or walk-through of the model. This tests the system logic and predicts actual usage characteristics.

The high level conceptual information model developed in this project provides a framework from which a more detail design can be developed. It is a high level blueprint of the intended product. Like a blueprint, however, as the actual product is being designed in detail, improvements and/or compromises must be made and these changes, modifications, and/or additions must be added back into original blueprints in order to accurately represent the "physical" product. If the product is only a component of a whole assembly, such as the outfit planning function is to the whole shipbuilding data base definition, then the design may need to be even more flexible to change since

the other components' design will have some effect on it. Proper maintenance methods are not well defined at this point, however, and this will be an area of concern if an actual outfit planning data base is implemented.

The same design steps and modeling methodology as described here for high level conceptual modeling can be used to create a much more detailed data base definition. The graphic nature of the model allows expert reviewers to quickly and accurately understand the design and will also provide the basis for the further expansion of the model.

SECTION 3 - THE HIGH LEVEL DATA BASE DESIGN MODEL FOR OUTFIT PLANNING

The data base design model developed in this section of the report is a high level conceptual view of the informational requirements necessary to support outfit planning in a shipyard. It is a framework from which an indepth, detail data base design could be developed. The modeling technique used3 does not require indepth training for a reader or reviewer to understand even though the development of an information model is quite involved. This ability to communicate clearly and concisely with the expert and non-expert in data base design/management is one of the greatest strengths in a modeling technique. There are only a few important modeling considerations to keep in mind, and they soon become reflective, so that the reader/reviewer can focus mainly on the content and accuracy of the information relationships established. The figures have been laid out with a narrative to facilitate the basic diagram reading and the textual description highlights the important information relationships and outfit planning concepts.

A brief description of the modeling symbolism is also useful to facilitate a more indepth understanding of how to read them. First, Figure 2 presents the basic entity class symbol. As defined previously, an entity class is an information category which contains several individual occurrences or members (or filing cabinet drawers full of files). Each member of the entity class can be identified by one or more attribute classes called identifying attributes.

The only other symbol used in this modeling technique is the relationship lines which connect the boxes (entity classes). Figure 3 explains how these are to be read. In all the specific model breakouts (Figures 4 through 11) all the relationship labels are to be read from the top of the page downward.

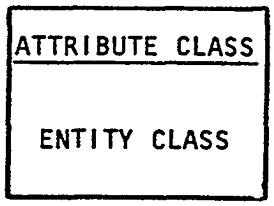


Figure 2. Entity class symbol for data base design. Each entity class represents a set of members which can be uniquely identified based on an identifying attribute class.

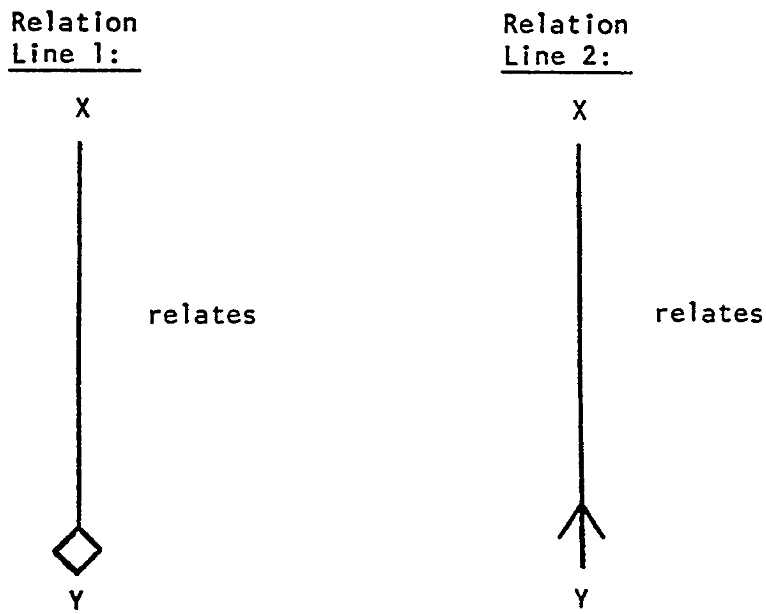


Figure 3 Relationship lines for data base design. For the first line, top to bottom: X relates to zero, one, or many of Y; and bottom to top: for each member of Y it relates to exactly one member of . For the second line, top to bottom: X relates to zero or one Y; and from bottom to top: each Y relates to exactly one X.*

They can be read in the other direction only by interpreting the relationship label using the proper "reverse logic" also explained in Figure 3.

The best way to understand the overall model is to look at categories of information or logical groups of entity classes. Information needed to support outfit planning has been divided into seven groups of entities by the topical areas of contractual , systems and structural planning, outfit planning, process planning, part fabrication, monitoring, and procurement information. In the next several subsections each area is analyzed focusing on its contribution to outfit planning. Finally, the whole model is presented to show how each area contributes to the overall data base design. (It may be useful to some readers to scan in advance the holistic data base model given later, Figure 12, then return to the detailed category descriptions here. Note also that the Appendix contains a glossary of the entity classes used in the model.)

<u>Contractual Information (Figure 4)</u>

Contractual information directly affects the way in which the shipyard can do business and, therefore, affects outfit planning. A sales contract is awarded which specifies several contractual requirements which the shipyard must fulfill to satisfy the customer. These could include quality assurance, inspection, engineering and performance requirements, etc. If a detailed information model were to be developed, each type of contract requirement might constitute its own separate entity class; however, in this high level view it is simply important to realize that they exist and can be identified. The most significant contractual requirements relating to outfit planning scheduling are those that either explicitly or implicitly determine or suggest milestones for ship construction.* The sales contract is also the legal document that allows the shipyard to establish an accounting vehicle by which to

* A "milestone schedule" is not an entity class of its own because it is already implied indirectly by the fact that a milestone is traceable to a specific sales contract and more specifically, to each ship type version. A milestone schedule is simply the collection of all the individual milestones for a given contract and ship so it would not provide any information not already identified in the model. This is a good indication that "milestone schedule" is a physical report requirement and not an information entity class per se.

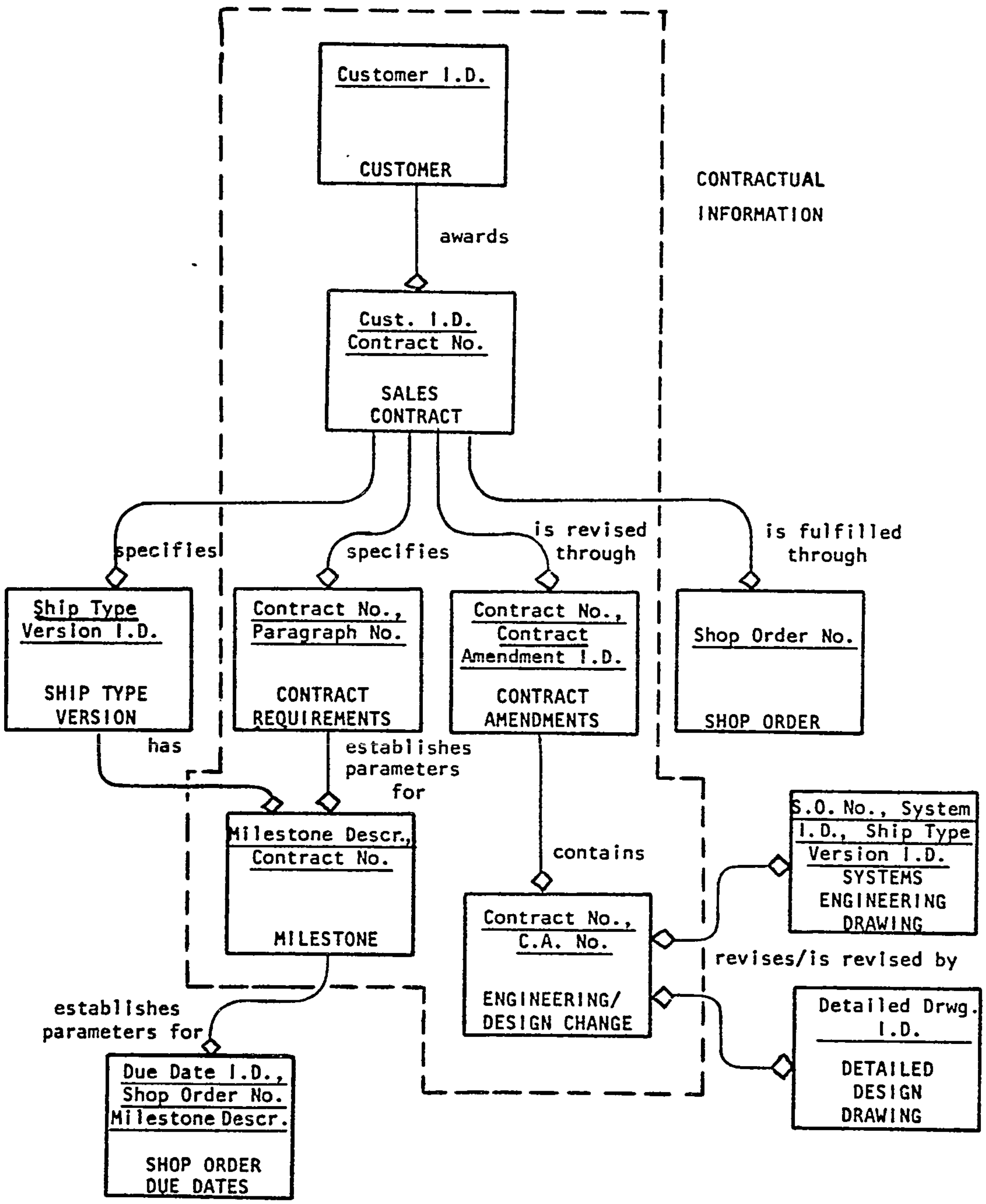


Figure 4. Contractual information needed to support outfit planning. A customer awards 0, 1, or many sales contracts. Each sales contract specifies 0, 1, or many ship-type versions and contract requirements. A sales contract is revised through 0, 1, or many contract amendments and is fulfilled through many fabrication and assembly shop orders. A contract requirement establishes parameters for 0, 1, or many milestones which, in turn, establish parameters for many shop order due dates. A contract amendment contains 0, 1, or many engineering/design changes. A systems engineering and detailed design drawing is revised by 0, 1, or many of these engineering/design changes.

charge time and cost against the client. In this model a sales contract is fulfilled through several shop orders. A shop order is the internal work authorization for a work package which allows production to charge against the project. The assumption here is that there is one shop order for every work package. In a detailed representation of an information model this relationship would have to be examined more closely. If the shop order represents the work authorization for a work package, it is important to realize that the shop order due dates must be established as a function of scheduling. This is done by using the various milestones for a given contract to establish logical shop order due dates, In other words, each milestone will establish parameters for several shop order due dates.

As with any sales contract9 there are usually several contract amendments negotiated between the shipyard and the customer while a ship is being built. Presently, it is quite a clerical achievement to keep track of all the revisions; however9 with a computer data base that is structured to be information independent 9 updates need only be made in one place. The contract amendments that are of considerable importance to outfit planning are those that contain one or several engineering and/or design changes. A systems engineering drawing and a detailed design drawing could need revision as the result of one or many engineering design changes, However, the reverse is also true: for a given engineering design change, it could affect one or several systems engineering (and/or detailed design) drawings. This redundancy was left in the mode1 deliberately to illustrate (1) what the double diamond on the relation line means9 and (2) how to tell when more information is required to make the mode1 meaningful,

A cross-reference entity serves to relate two information entities together in a more meaningful way than the "many to many" relationship which exists between engineering design change and systems engineering drawing as well as detailed design drawing0 Thus, in this case, a cross-reference is needed to resolve this relationship in a more detailed model to clear up these relationships, and Figure 6 would be one solution of the information relationships. In a high level conceptual view, these cross-reference entities could be left out9 but for the sake of a more thorough design they have been included where needed in the rest of the data base design model.

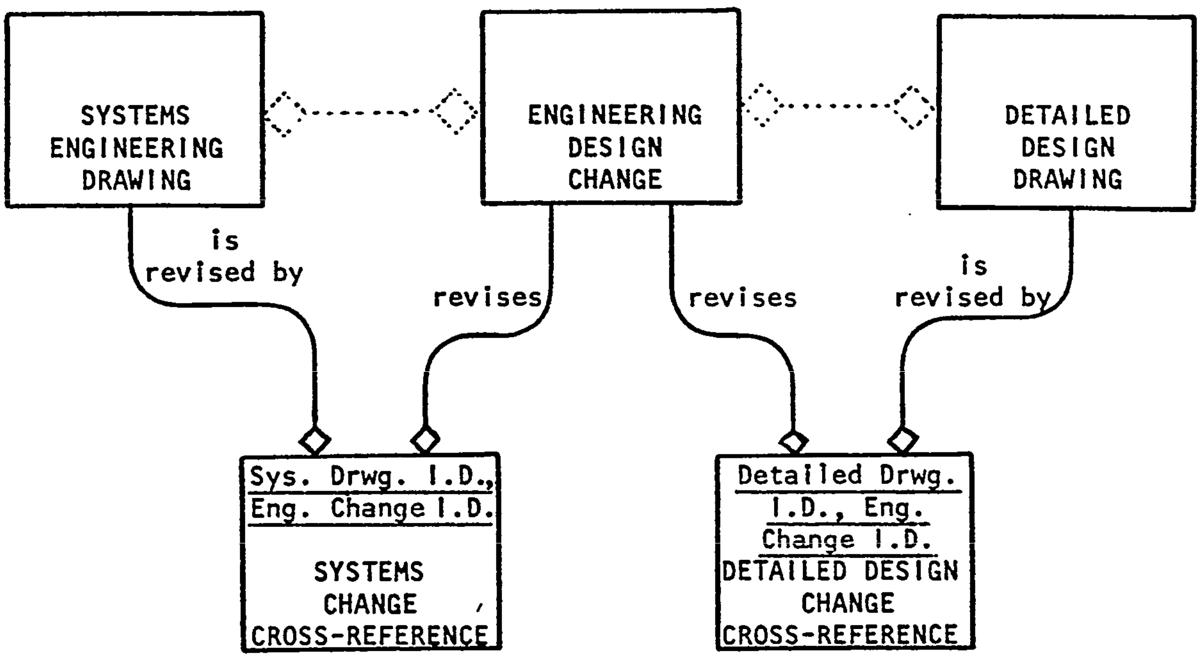


Figure 5. Resolving redundancies. In this case each instance of a drawing revision could be cross-referenced back to the engineering design change that caused the modification. Note that the identifying attributes on the cross-reference box will be unique. This then eliminates the double diamond or many-to-many relationship that existed before.

Systems and Structural Planning (Figure 6)

Outfit planning requires systems engineering design in order to "transition" to a pallet-oriented detailed design. In the normal course of ship engineering design a given ship type version is divided up into several systems. Each system is then described in detail by many systems engineering drawings. This is true in both the United States and Japan. At some point in the system engineering design, however, the Japanese begin to break the systems down into zones, so for any system it can be cross-referenced into its respective zones. This breakdown becomes official as the Japanese then take systems engineering drawings and reference them to produce detailed design drawings.

Outfit Planning Information (Figure 7)

The most important aspect of this high level data base design model is the specific outfit planning information. All other categories are necessary to support outfit planning, but this category describes the information which is central to outfit planning itself. The key entity class is the pallet because it is the formation of the pallet in the design phase which allows procurement, scheduling, materials management, and even design more control over the actual production of a ship. A pallet is related to systems design through a detailed design drawing which can be directly cross-referenced to specific systems engineering drawings. The actual process of going from systems engineering drawings to detailed palled-oriented design drawings is what the United States has been calling the transition design of outfit planning though there is no real term for it in Japan.4 This transition design, however, is the single most important process in outfit planning (or any true production-oriented design in any manufacturing concern). Another way to view the pallet, however9 is by its physical location on the ship. Each zone has several pallets associated with it and each zone can be cross-referenced to major systems which run through it, so indirectly this provides another way to associate zones, systems, and pallets.

Other aspects which further describe or categorize a pallet are the stage and area. The stages are simply the on-unit, on-block, or on-board distinction of how a pallet is processed. A pallet can actually pass through all

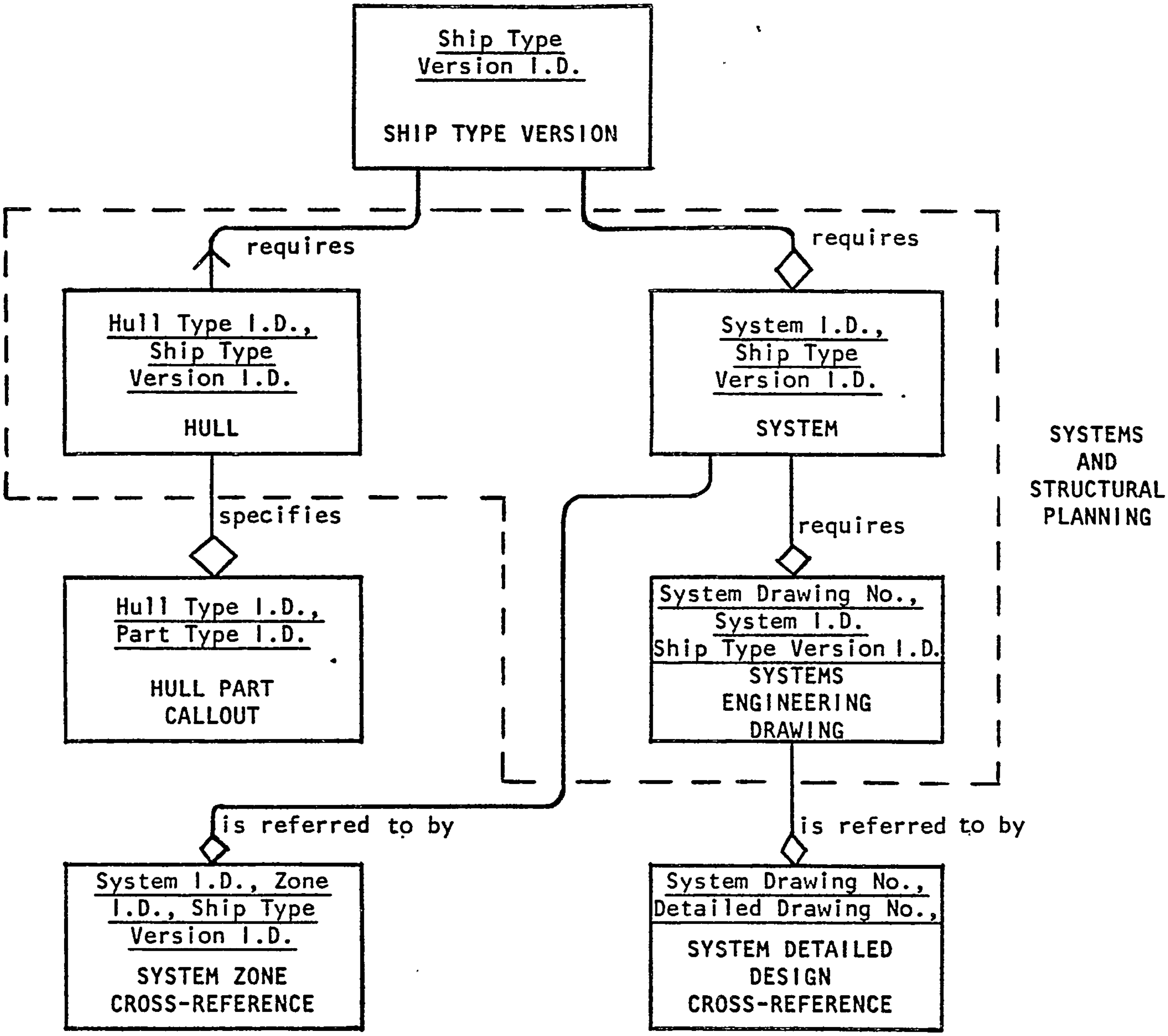


Figure 6. *Systems and structural information necessary to support outfit planning. A ship type version requires zero or one hull type and requires zero, one, or many systems. A system (i.e., piping, electrical) requires zero, one, or many systems engineering drawings to describe it. For transition design the systems engineering drawings are referred to by zero, one, or many system-zone and system-detailed design cross-references.*

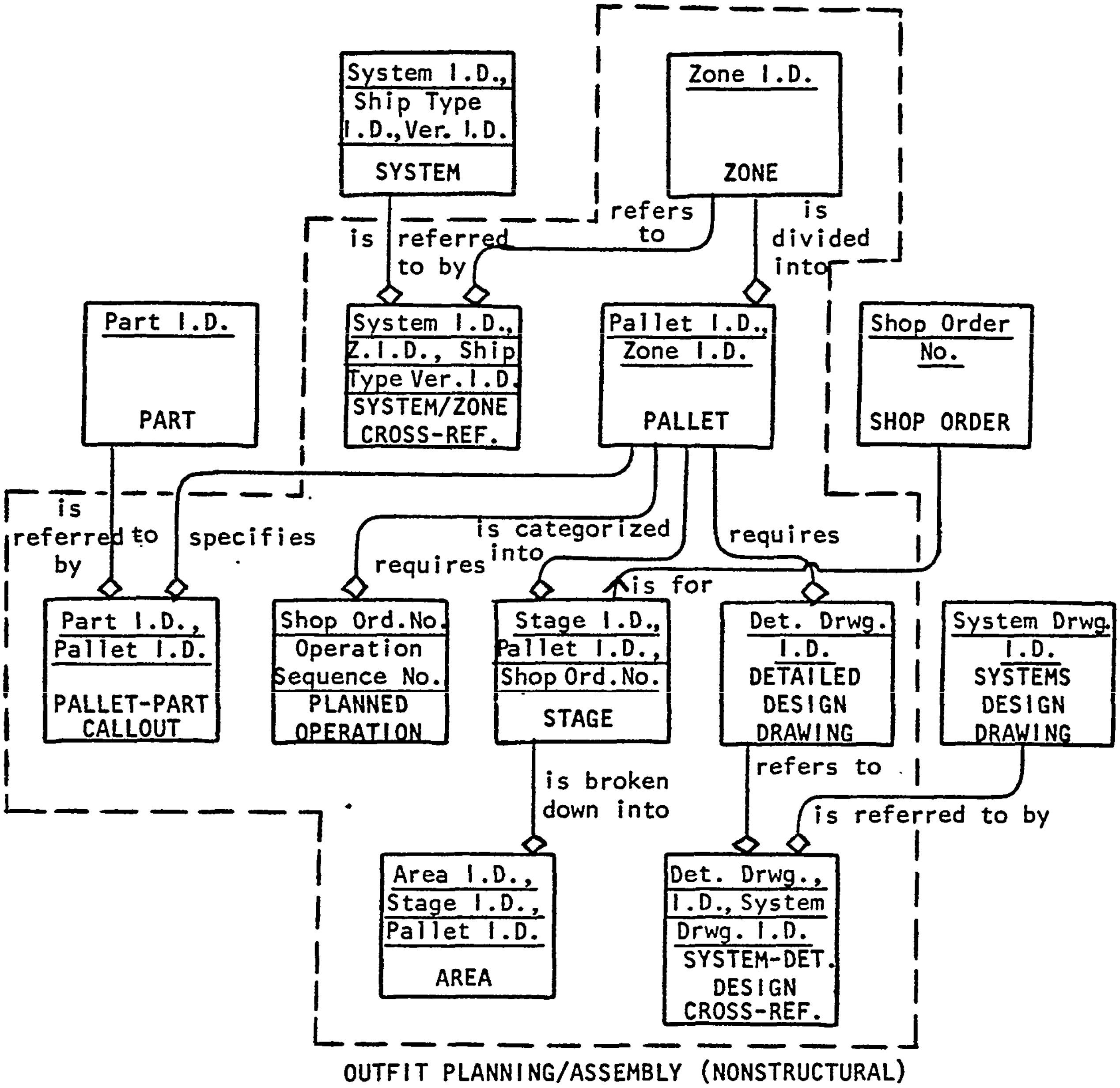


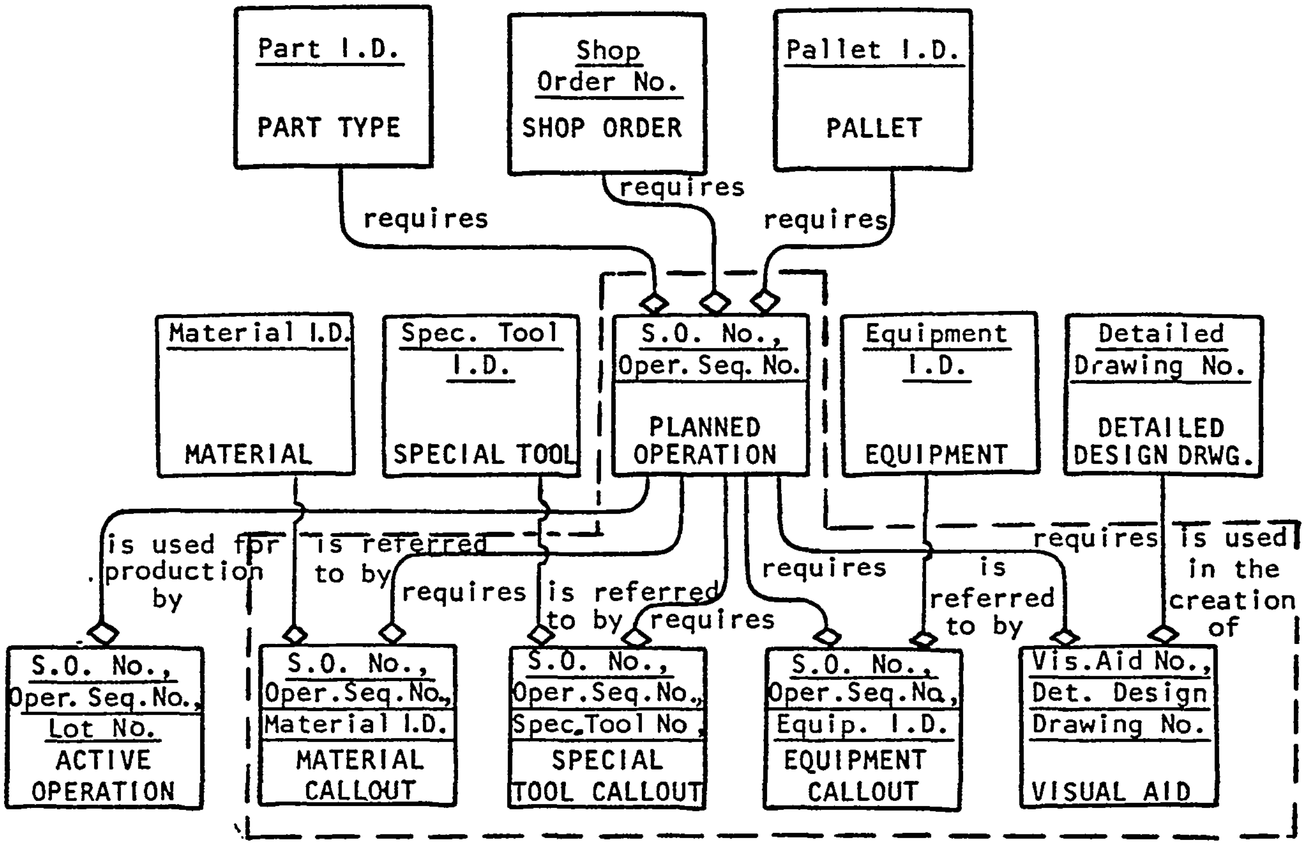
Figure 7. Outfit planning/assembly information. A zone is divided into zero, one, or many pallets, and a zone can refer to zero, one, or many system-zone cross-references (in other words, a zone has several systems running through it). A pallet is categorized into zero, One, or many stages which, in turn, are broken down into area categories. A pallet also requires **zero**, *one, or many detailed design drawings (which refer to systems drawings). A pallet requires zero, one, or many planned operations for assembly and specifies zero, one, or many parts of which it is comprised.*

three stages of production, if necessary, or lose its identity later as, for example, a unit becomes a small part of a block assembly pallet and so on. For any given stage of production (on-unit, on-block, or on-board) the Japanese have tried to define logical categories of processing to help them justify mass processing techniques and/or flexible tooling, jigs, and fixtures; these are often referred to as production areas or problem areas and are simply referred to as "areas" in this model. Notice that a shop order is related to a stage of production and to a set of planned operations. This confirms that a "work package" is really a process plan for a specific pallet at a specific stage of production; an important relationship which a data base design should definitely establish. By the time a pallet has been classified in zone, stage, and area, its process plan is almost established. Combine it with the detailed design drawing and, to an experienced worker, the production instructions are practically all defined; in fact, these are sometimes the only "process plans" given to experienced Japanese workers. However, it is still true to say that a pallet requires several planned operations whether implied, communicated verbally, or on a formal process planning form and the latter is recommended especially for providing instructions to inexperienced workers.

Process Planning Information (Figure 8)

The main role of outfit planning is to provide a more efficient and effective method of production and, therefore, needs the support of process planning information. There are two types of process plans, one for part fabrication and the other for assembly of a pallet. The combination of a shop order and a part requires several planned operations which constitute a part fabrication process plan, and it is the combination of a shop order, a pallet, and the stage of production (not shown in this view) which compose a pallet assembly process plan.

Regardless of the type of process plan, however, each planned operation requires the same type of information to support it. A planned operation calls out the use of materials, special tooling, and/or equipment in order to produce the product. Standard tooling is considered as a part of the planned operation description, but could easily be broken down separately, if desired, in a more detailed data base design model. For a pallet, a process plan could call out parts in the same way as materials are called out; however, it is the



PROCESS PLANNING INFORMATION
(FABRICATION, ASSEMBLY/CONSTRUCTION, INSPECTION INSTRUCTIONS)

Figure 8. Process planning information necessary to support outfit planning. There are two types of process plans, fabrication of a part and assembly of a pallet, each requiring the same type of process planning information. A shop order is either for part fabrication or pallet assembly (pre-outfitting) and requires therefore zero, one, or many planned operations. A part, then, requires **zero**, *one, or many planned operations or a pallet requires zero-one, or many planned operations depending on the shop order type. A planned operation requires zero, one, or many material callouts, special tool call-outs, equipment callouts, and visual aids, and is used for production by* **zero**, *one, or many active operations.*

interpretation of this model that it is really the pallet itself (see Figure 9) which calls out the part and not the planned operation. This is a subtle distinction, and the user would never know which way the callout occurred because the process plan report or form (i.e., physical piece of paper) would contain the same information on it, regardless.*

Part Fabrication Information (Figure 9)

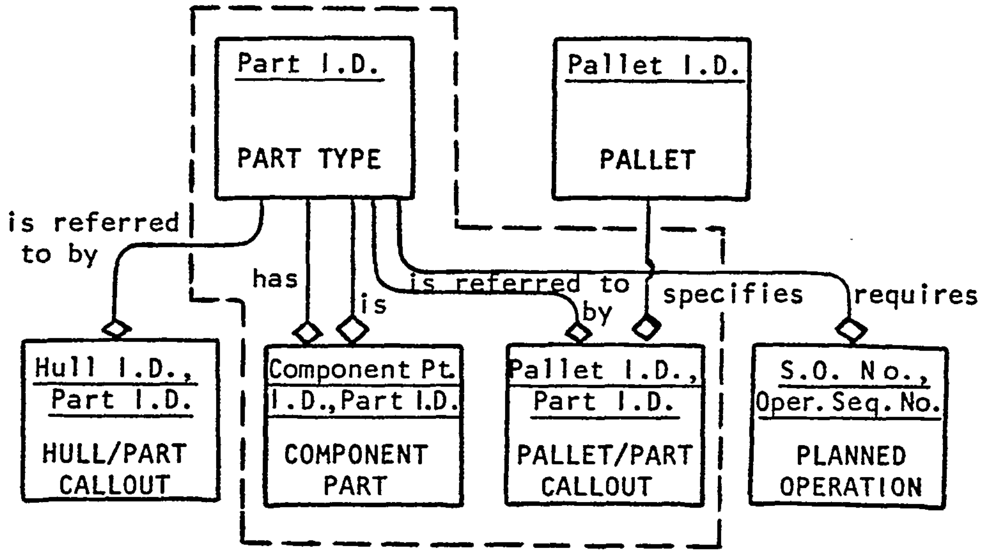
Outfit planning emphasizes the assembly nature of the shipbuilding industry. Part fabrication information, however, is required to support the assembly operations. When shop order (or work package) due dates are established (Figure lo), they are for both part fabrication and assembly operations. Schedules set up for assembly require that parts be available for production, whether they are made in-house or by a vendor before they can come together into an interim product (i.e., pallet). So, it is necessary to know how long it will take to produce in-house parts. This information is attainable from the accumulation of individual planned operations or process plan. Once this is known, schedules based on precedence can be set up for production.

A unique aspect of the part type entity class is that it has two relationships with component parts. This does not occur very often, but it simply means that a part type can have component parts and a part type can also be a component part at the same time. This is worth noting but it does not greatly affect the data base design, rather it is an anomaly of the definition and use of the term part type.

Fabrication, Assembly, and Erection
Monitoring Information (Figure 10)

In order to carry out and control outfit planning, there needs to be actual production information which serves as a progress evaluation tool. Once

* The reason for the distinction comes about because a pallet will have a bill of materials (list of parts) associated with it regardless of whether the process plan has been defined, but if the data base set up such that pallet-part callout "belonged" to the planned operation, a pallet-part cross-reference is not established until the planned operation is defined. A simpler way to look at it is to realize that pallet-part callout is identified by attribute classes. Neither pallet identification nor part identification, as an attribute, uniquely identifies a planned operation; thus, the callout would not work if it belonged to planned operation.



PART FABRICATION INFORMATION

Figure 9. Part information to support outfit planning. A part type my have zero,.one, or many component part types, and a part sometimes is a component part of some other part. A pallet and a hull both reference, or are comprised of, many parts so in order to have a bill of materials there must be a number of callouts to each part type. Also, for a **fabrication-oriented** *shop order, each* **part** *type requires zero, one, or many planned operations. When a part requires several planned operations, it is called a fabrication process plan.*

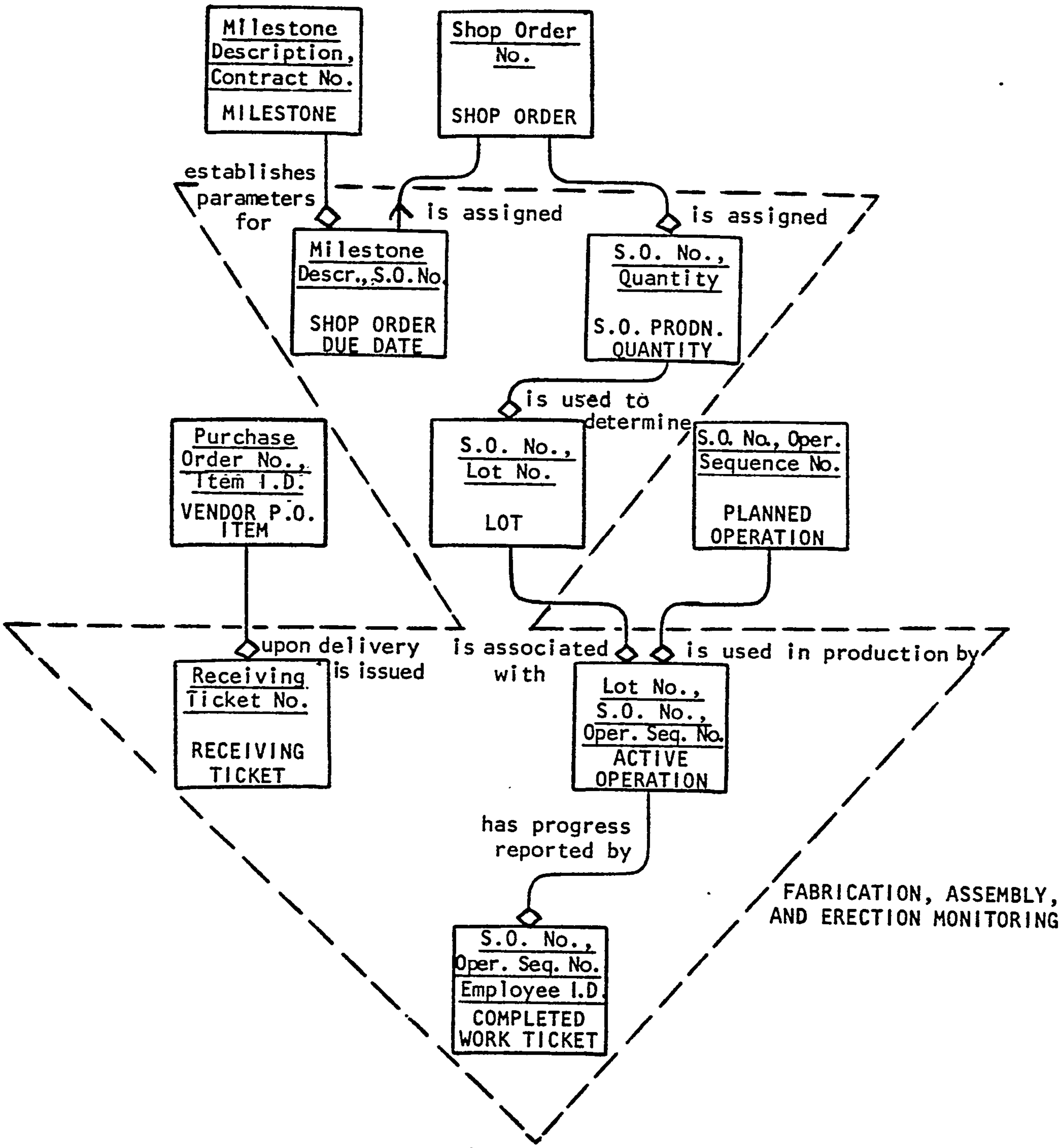


Figure 10. Fabrication, assembly, and erection monitoring which supports control necessary for outfit planning. A shop order is assigned a due date based on parameters set forth in a milestone. The milestone due data determines several shop order due dates. A shop order is assigned one or more production quantities (depending on whether it is a part or pallet S.O.) which in turn are broken down into one or more lots. A planned operation is used in production by zero, one, or many active operations, and each active operation is associated to a lot number with any particular shop order. The status of an active operation is usually reported by several completed work tickets. Procured materials are similarly accounted for by a receiving ticket.

the shop order is assigned a due date and a desired production quantity, it becomes important to monitor how well they are executed. A shop order production quantity is produced in one or more lots, especially for part fabrication, but it is also possible to assemble more than one pallet (i.e., when a unit is a standard assembly item). The distinction between an active and a planned operation is that the "active" operation is the actual process in action. This active process is for one particular lot of a shop order. The reason for having the information entity active operation tie together the lot and planned operation is for production traceability. In contracts where numerous contract amendments are made, their effect on production needs to be known. One way to do this is to see, in the case of a planned operation change, how many parts have already been produced and are being produced to the old specifications. Having this ability resident in a computer data base would provide much more control in determining the effects of an engineering or production change. In this design model a completed work ticket has been selected as the information entity class which reports progress to an active operation; however, there can be a variety of ways to actually report the job status.

Also, a link in the monitoring and control activity comes in the shipping and receiving department. In this case, the receiving ticket reports when a vendor purchase order item is in. This not only assists in monitoring vendor delivery commitments, but it also signals production control that an item i.e., part) is in stock and available for production.

Procurement Information (Figure 11)

Outfit planning provides a great opportunity for procurement to control and schedule purchases. By the same reasoning, however, it is important to realize that at least some basic information is needed from procurement in order to support outfit planning. The ability to relate shop orders to purchase order items provides two advantages to outfit planning. First, just as part fabrication and assembly processing times are needed to determine schedules, so are vendor delivery capabilities. Once estimates or formal vendor delivery schedules are set up, the impact on the rest of the production schedule can be determined. Long lead times always cause problems, but with the many work packages or pallets defined in outfit planning work could be more easily rearranged to meet milestones than with the larger work packages of a

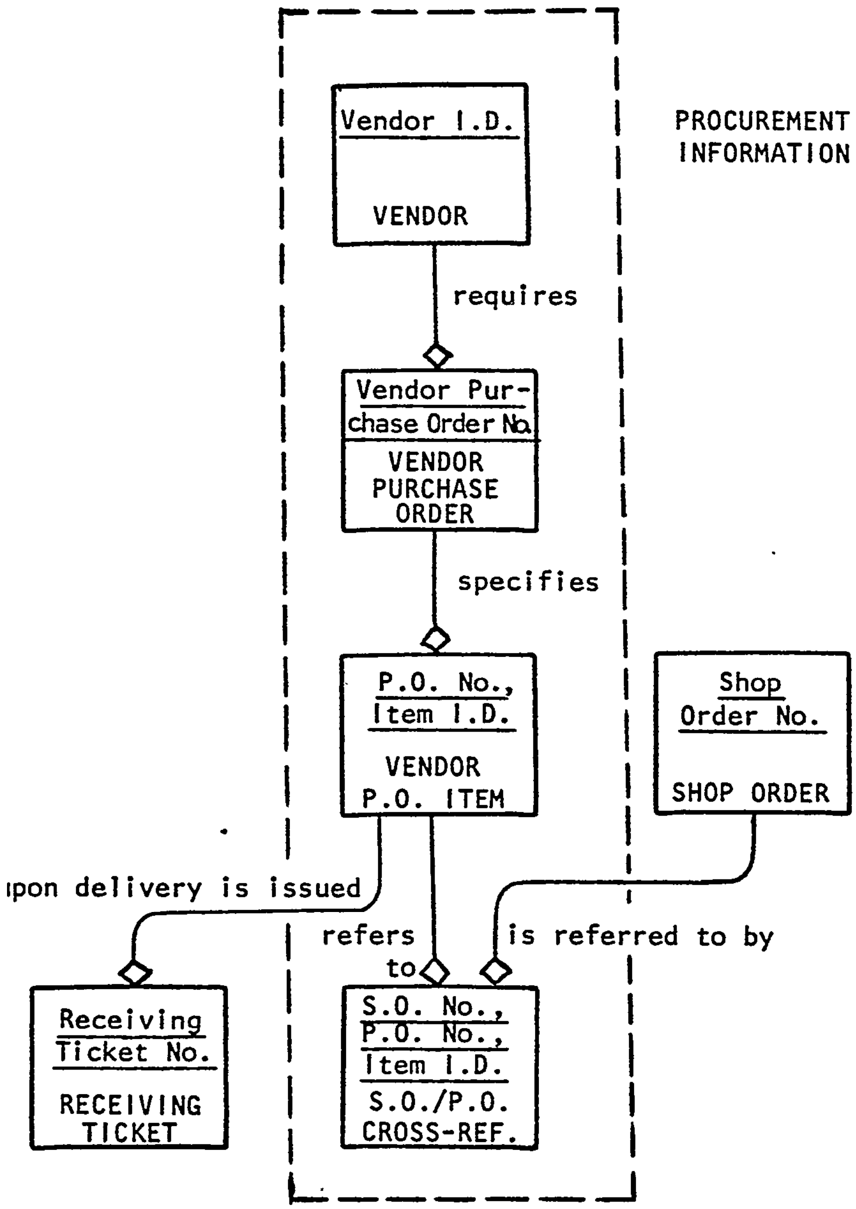


Figure 11. Procurement information supporting outfit planning in actual production. A shop order authorizes that a pallet be prepared. In the procurement activity it is important that materials purchased can be cross-referenced to the proper shop order. Conversely, it is important to production that they be able to assign incoming material to a specific pallet. This reads as follows: A vendor requires zero, one, or many purchase orders. A vendor purchase order may contain zero, one, or *several items. Each item is issued a receiving ticket when it is accepted by the company, and each item is traceable to a shop order through* a *cross-reference file (e.g., bill of materials, procurement cross-reference lists).*

system approach. Secondly, the ability to trace deliveries to the proper work package (shop order) is crucial to the pallet production concept. Instead of carrying such large in-house inventories, which is quite expensive, most of the material should be scheduled to arrive from the vendor "just in time" for the pallet to be compiled for assembly or production which saves inventory carrying costs. This means that specific items go to specific shop orders, and not only is a matching ability required, but also some way to record that a matchup did occur. So not only does outfit planning provide more control for procurement, but procurement needs to be more "controlled" in order to handle this extra attention to detail. There will be a lot less room for allowance (slop) in the system.

Overall Model (Figure 12)

Now that the information categories have been explained in detail, it is important to view the entire data base design model to gain a holistic systems perspective. The purpose of a data base is to provide storage and retrieval of information for an organization and in this case even more specifically for outfit planning. A data base design provides the structure or framework around which information can be "filed away" and "reported back" in an efficient and cost-effective manner. To test the usefulness of a data base design, one must look through the eyes of the users of the system to see if their information needs are being met. One way to do this is simply to think up questions or "queries" that the data base would need to be able to provide information to answer. Some queries that this data base design model can answer are:

- How many contracts are there from any one customer
- How many ships are to be built per sales contract or per facility (what is the backlog)
- What are the milestones
- What are the contractual requirements
- How many contract amendments have there been on a specific contract
- How many contract amendments affected engineering and/or design changes
- How will an engineering/design change affect
  1. Design
  2. Production
  3. Procurement

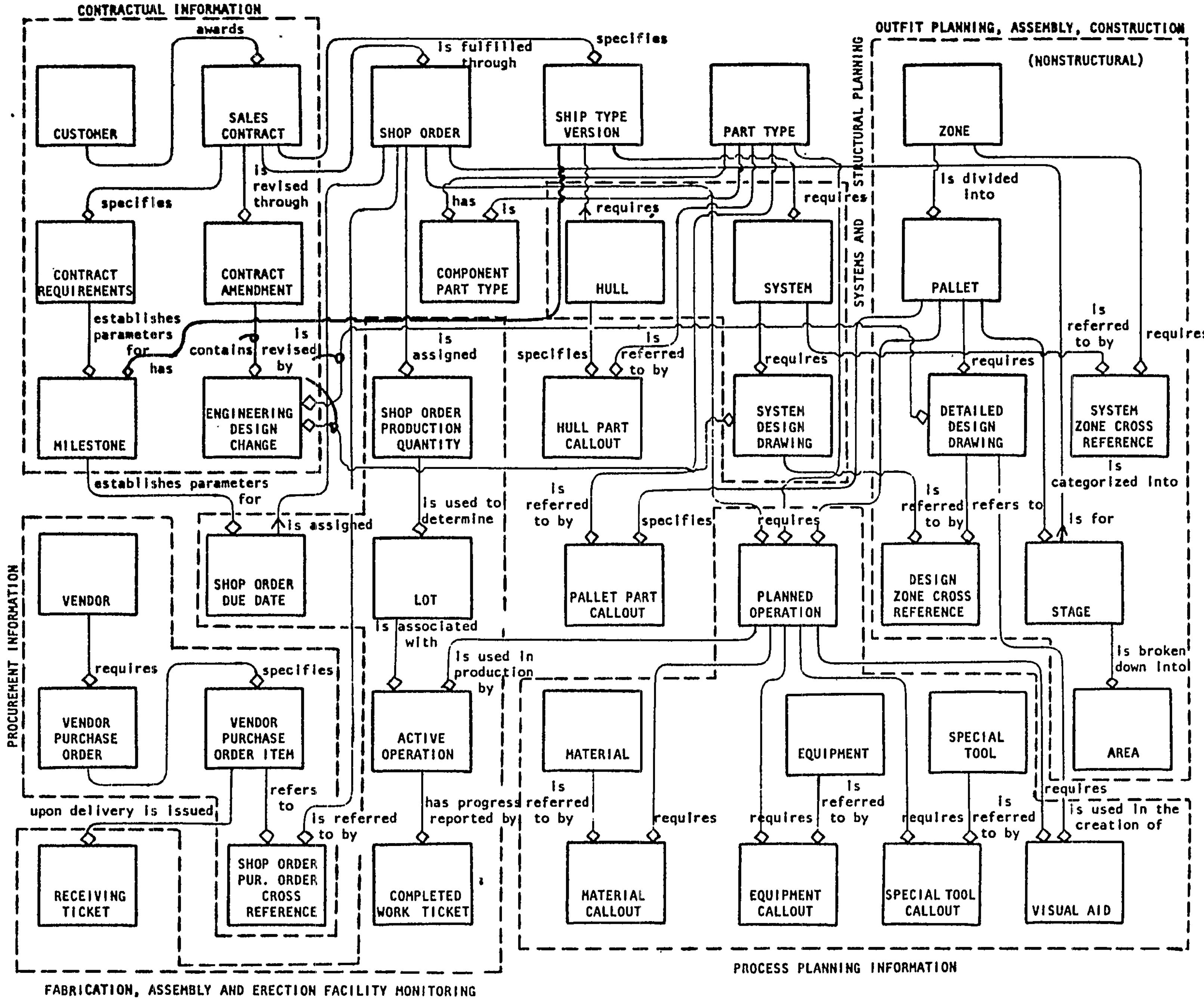


Figure 12. Overall conceptual design of a data base model for outfit planning.

- 0 How many shop orders are there on a contract
- 0 How many shop orders have been completed
- 0 How many were finished on time, late, or early
- 0 How many pallets are there in a ship type version zone
- 0 Have all the parts come in for a specific pallet
- 0 Which systems engineering drawing were referenced in a detailed design drawing
- 0 What is the material list for
  1. Total materials required
  2. Procured items
  3. Pipe shop
  4. A pallet
- 0 How many pallets are on-unit, on-block, or on-board
- 0 How many pallets are in a given area (production/ problem area)
- 0 How much fabrication work needs to be done
- 0 How many direct labor hours to build the ship
- 0 What kinds of materials, equipment, tools, parts, etc., are needed
- 0 What is the overall ship construction schedule
- 0 How many shop orders are being worked on right now

The value of the data base design is worth the value management would place on the ability to answer important questions in a timely manner.

SECTION 4 - HOW TO FURTHER DEVELOP AND USE A DATA BASE DESIGN MODEL

A data base design and a data base management system (DBMS) need to be distinguished for a full perspective on the computer information handling environment. A data base design sets up the filing structure and information entity relationships, and a DBMS is required to actually administer that structure and manage those interrelationships. A DBMS can be described as a software system devoted to the management of interrelated data collection.[1] In this context, then, the data base design is the definition of those data collections and interrelationships. It is much more important to have a well-organized filing system (data base design) than it is to have a speedy file clerk (DBMS). This does not suggest that a DBMS is not important, because at some point the two have to work well together or the overall system will suffer.

A data base design which has been described in this report is independent of any DBMS. This means that it can be incorporated into most DBMS's without major entity redefinition or relationship changes. The design model provides a conceptual framework around which the actual information can be fed into it. Once it is defined in detail, a DBMS which best suits it can be selected.

This high level data base design model for outfit planning provides the first step in seriously analyzing the information environment of a shipyard. The next step would be to develop a detailed data base design model (which would probably be two to four times the size of this one) preferably geared to implementation in a specific shipyard, though a generic detailed model could be established. Then the physical environment for an actual prototype system must be defined. The conceptual modeling technique does well up until an actual implementation plan needs to be established. At this point statistical analysis and specific data base management systems need to be used and decided upon, respectively, before the data base is actually built. The physical parameters of a data base are fairly easy to conceptualize. They involve finding out how many "files" go in the drawer (how much data goes into an entity class) and which drawers are used the most and which relationships are the most important. It would be quite feasible to actually simulate and perform statistical analysis on this for an actual shipyard. Depending on the detailed design of the data base, the DBMS choices should be narrowed down. Each DBMS has its strengths and weaknesses, and based on the statistical analysis, the DBMS should be chosen which most cost effectively correlates to the most important features of the data base design.

DATA BASE DESIGN CONCLUSIONS

A data base is dependent on what a company desires to use information for and how they wish to access that information. An effective data base design for support of outfit planning must relate information directly to design engineering and must also be accessed by procurement, production control, process planning, structural planning, material handling, and quality assurance. The most flexible data base designs attempt to maximize information/data independence, nonredundancy, relatability, integrity, accessibility, and shareability. Using a logical sequence of design steps and a conceptual (graphic) modeling technique will produce a data base design of this type which ensures

that the basic systems requirements are met and that system evolution will be consistent as demands and technology changes affect those requirements. This study has produced a conceptual data base design model which covers all of the important information issues that affect outfit planning at a high level. A much more detailed model could be developed using the concepts established in this study as a cornerstone.

The importance of timely and accurate information to the proper functioning of a company cannot be overemphasized. Information and communication are the underlying supports to every activity of a company and Figure 13 illustrates that a data base (information) is the central element which binds the other activities together. It is for these reasons that flexible and thorough data base design techniques must be used to support a major company undertaking such as outfit planning. In fact, outfit planning provides the justification for developing such an elaborate system.

DATA BASE DESIGN RECOMMENDATIONS

There are three possible avenues to pursue in developing a more detailed data base design to support outfit planning.

Develop a Generic Shipyard Data Base Design

The first alternative is to develop a detailed data base design model based on an indepth study of several representative shipyards. This model would be "generic" in the sense that all information requirements of the study of the shipyard would be incorporated into the model, as it applies to outfit planning. This may even include an indepth analysis of a Japanese shipyard, such as one of IHI, to use as benchmark since it would be the only actual fully outfit-planning-oriented operation studied. This requires a large level of effort, but the end result would be a very thorough model which could be applied with minor modifications by any U.S. shipyard. A prototype data base should be built and tested with actual ship design and production data, or at least simulated.

Develop a Company-Specific Data Base Design

Since a few U.S. shipyards are already involved in implementing many of the aspects of outfit planning, a study could be done that develops a company-specific detailed data base design model. The model is much more company-specific in this case, but if the proper modeling methodology is used (like

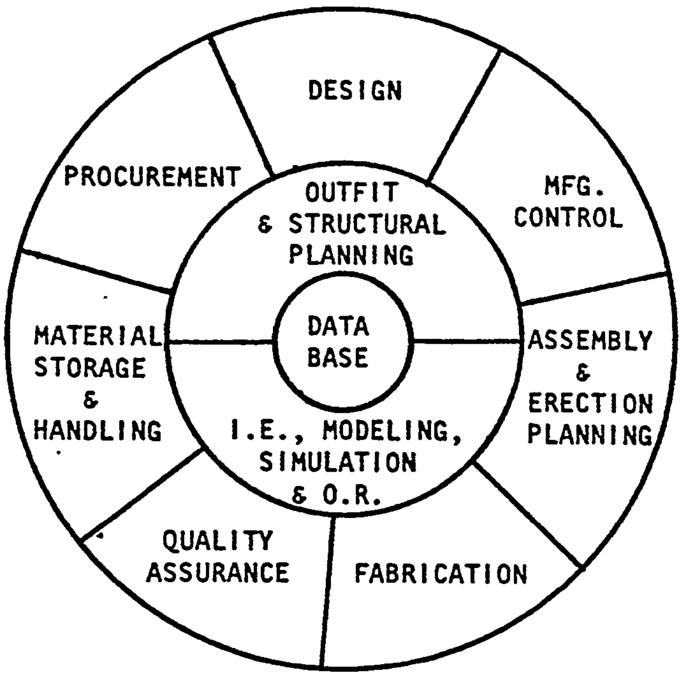


Figure 13. Shipyard activity wheel. A common or central data base can provide the support necessary for an integrated approach to all the activities of a manufacturing concern. For a shipbuilder, outfit and structural planning are key tasks with overall support from industrial, manufacturing, and systems engineering and their associated tools of simulation, modeling, and operations research. Planning and engineering provide the basis by which the actual or physical "doing" of ship production is accomplished (the seven outer tasks). Information and communication provide means by which all decisions are made and therefore represents the core or cornerstone of an effective organization.

the one in this study), the results can be beneficial to the U.S. shipbuilding industry in general. Other shipyards, with some effort, can take this company specific model and modify it to suit the needs of their facility.

Encourage Development to Occur Individually

The conceptual data base design developed in this study is a sound base line for an individual shipyard to begin planning for outfit planning information requirements. In this context, it may be adequate simply to encourage those shipbuilders who are implementing outfit planning concepts to develop their own detailed data base design models. Since this requires a reasonably large level of effort, there should be some incentives provided to encourage a thorough job. If the information is available to the public domain, it greatly reduces the types of funding assistance and the contribution to the industry in general. Nondisclosure could be accomplished (1) for defense work through a TECHMOD (business deal) by allowing data base design to be included as one of the joint funding ventures of technical modernization, and (2) for a commercial shipyard, where joint funding for IREAPS members is possible if their suggestions are approved, though this would involve some information dissemination to the IREAPS member company. Other possibilities may exist for nondisclosure, but these two are the most obvious.

The best choice of the three development recommendations simply depends on the objectives of the funding agency or shipyard(s) that have an interest in pursuing it. The most beneficial approaches in a U.S. shipbuilding capabilities sense are those which disseminate the project results to the industry as a whole.

SUMMARY OF CONCLUSIONS

There is nothing that other shipbuilding nations have done that the U.S. shipbuilders cannot do. In fact, most of the productivity differences have not occurred "cataclysmically", all at once, but rather have evolved over a period of time. By the same reasoning, for the United States to regain a favorable competitive position will take a number of years. To illustrate this evolution, the following list summarizes many points of "Japan's Phenomenal Shipbuilders":[5]

What has Japan done right:

o Rationalization of shipyard procedure

o Luxury of large dry docks (coincidence?)

o World War II necessities
  - block assembly systems
  - semiautomated welding
  - advanced fitting-out
  - standardization

o Time for engineers to rethink the processes (recession between 1946 and 1954)

o Introduced by a U.S. firm
  - assembly line methods
  - prefabrication of large sections

o Diversification into related fields

o Economical hull forms (bulbous bows)

o Thinner steel plate

o Large cranes (large load capacity)

O Constant infusion of engineers (700 per year).

None of these methods by themselves were incredibly ingenious, even though some (if not many) of the applications were imported from the United States. So the shipbuilders of Japan are phenomenal not through the use of some secret productivity weapon, but rather they are phenomenal because they have effectively and efficiently managed their operations, paying particular attention to detail and emphasizing good engineering practices--something that many U.S. shipbuilders and many U.S. companies in general have not done well in the past. There are no real barriers to stop U.S. shipyards from excelling in the future. A recession can be a good time to rethink and reorganize, and many U.S. shipbuilders are already on the road to recovery. It is the hope that this study will contribute to that end by explaining and defining the high level information/data base requirements needed to support outfit planning.

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RATIONALIZATION OF SHIPYARD INFORMATION FLOWS FOR IMPROVED SHIPBUILDING PRODUCTIVITY

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Mr. Steller, an Associate in the Maritime Group of Temple, Barker & Sloane,Inc. (TBS), is a specialist in shipbuilding operations. Mr. Steller has assisted a major U.S. shipyard in preparing for major naval contract bidding by developing work monitoring and cost/schedule control systems, designing and planning the organizational approach, and improving cost-estimating capabilities. In addition, he performed a competitive analysis of the U.S. shipbuilding industry and acted as Manager of Strategic Planning. Other studies he has participated in include a strategic assessment of the performance, capabilities, and competitive position of a U.S. shipyard and a rationalization of management reports and information flows at a major U.S. shipping company.

Mr. Steller received a B.S. (with highest honors) in marine engineering and marine transportation from the United States Merchant Marine Academy, an M.S. in naval architecture and marine engineering from the Massachusetts Institute of Technology, and an M.B.A. form the Harvard Graduate School of Business Administration. He is a registered professional engineer.

ABSTRACT

This paper provides a practical approach to rationalization of shipyard information produced by and received by shipyard employees. An improvement in the yard's productivity is gained through better quality and timliness of management information, elimination of redundant or unnecessary reports, streamlining of reports and reduced distribution of the information. The process to achieve these goals is based on a micro computer-assisted analysis of existing information flows and inventory of reports and management information. The process to achieve these goals is based on a micro computer-assisted analysis of existing information flows. An inventory of reports and management information is developed to include distribution, frequency, computerized vs. manual production, size, and use of the information. Based on the analysis, recommended rationalization can result in productivity gains (effective use of management and indirect labor time, timely and accurate decision-making, improved operations management, etc.) and in cost reductions (reduced report production, distribution, and computer costs, minimization of manufacturing error, smaller indirect staff, etc.).

RATIONALIZATION OF SHIPYARD INFORMATION FLOWS FOR IMPROVED SHIPBUILDING PRODUCTIVITY

Presented by Mitchell E. Steller

Increasingly, managers are being deluged by information, only a portion of which supports, formally or informally, the decision making process. The quality of management decisions must be of primary concern.

Ultimately, shipbuilding and repair is managed on a unified, multidisciplinary level by a relatively small number of people. Of the 170,000 shipyard employees in this country, some 36,000 (more than 20 percent) are not engaged in production. The percentage of non-production personnel has increased over the last decade (Exhibit 1). These are the presidents, vice presidents, managers, superintendents, foremen, planners, engineers, accountants, systems analysts, draftsmen, purchasers, and program managers. Their direct variable cost in this industry amounts to $1.5 billion--about 15 percent of the business and about 30 percent of the value our industry adds to the material and subcontractor services it consumes.

These 36,000 persons affect the product through processes. They make virtually all the decisions in the business.

- What to bid
- How to budget
- What to buy
- When to buy
- How to build or repair
- How to man the job
- How to identify changes
- How to react to changes
- How to predict problems early
- How to successfully manage problems

These decisions are made by plan or by default, explicitly or implicitly. To make them by plan and explicity requires communication and information. Information is useful only when organized and when it flows effectively.

- **Information must be designed and managed.**

- Information must be generated efficiently--so that those who prepare it can concentrate on using it.

- Information must flow to those who need it--and not to those who don't.

In the course of consulting assignments, Temple, Barker & Sloane, Inc. has developed and used a conceptual and practical methodology to help maritime organizations understand the generation and flow of information and to improve the efficiency and effectiveness of this exchange of information.

PROBLEM DEFINITION

The general problems that lead to inefficient information flows include:

Design Problems.

- Redundant information generation and flow
- Unnecessary information generation and presentation
- Lack of summarization--providing the same detail to several organizational levels
- Lack of consistent organization of information from report to report
- Poorly organized information in formats that hinder use.

Generation Problems

- The need to manually operate on information from separate computer systems that don't "talk" to each other.
- Using manual labor to summarize computer information
- Providing information more frequently than it is used
- Relying on erroneous information that requires manual effort to reconcile errors

Flow Problems

- Distribution to people who don't need the information

- Accumulation of information upward and redistribution downward with little or no analysis

These problems boil down to too much paper, wasted management time and money, and management receiving ineffective information, too late. Too often marine managers lose sight of the forest in the trees.

OBJECTIVES OF INFORMATION RATIONALIZATION

The objectives of the methodology are as follows:

1. Provide quality information to management. The information should be pertinent and of the appropriate level of detail for the targeted manager.

2. Provide timely information linked to the requirements of the individual manager's job. Depending on the person, information may be used for day-to-day operations, weekly or monthly performance monitoring, or long range planning and development.

3. Provide accurate information. A rule of thumb is information quality and usefulness diminishes by 25 percent for each level of management through which it is passed.

4. Provide well formatted information, i.e., easy to use and understand.

5. Deliver the information efficiently. The delivery mechanism can be automated or manual but in either case should be tailored to the requirements of the manager and should minimize the use of scarce resources.

APPROACH TO RATIONALIZATION OF INFORMATION FLOWS

The first step of the approach to support these objectives is to catalog all of the the management reports and information flows generated in the organization. Management surveys or questonnaires are an effective means to identify and collect samples of each report and can also provide insight on the flows, intended purpose, usefulness, and effort associated with each port.

Next, a microcomputer report management program is used to manage the volume of formal and informal, manually prepared and computer-generated reports in a shipyard, we have developed. Key data inputs to describe the reports include the following:

- Name of report/information
- Producer (coded by organizational level and function)
- Receivers (coded by organizational level and function)
- Report size and frequency of distribution
- Production of report/information, i.e., manual or computerized,
- Time period covered by the report,
- A keyword analysis to describe reports.

An example is included as Exhibit 2.

This report management database and its associated program support the evaluation of each report on the basis of:

- quantity (number of reports, pages)
- quality (perceived usefulness)
- purpose (intent, actual use)
- flows within the organization

Quantity is evaluated in terms of pages per year and is found from the report size, frequency, and distribution list. The determination of quality is more subjective and difficult. The reports can be generally categorized as:

1. Intelligence level reports present information about the outside environment in which the shipyard operates, e.g., competitor activities, economic forecasts, market trends, etc. Intelligence reports answer questions about things external to the company.

2. Activity level reports present only status or activity information about the company,

3. Control level reports present status or activity information and compare this information to standards, plans, or projected results. Control report do not include analyses of the reasons for observed differences between actual results and expected results.

4. Analysis level reports present status or activity information and compare this information standards, plans, or projected results. Analysis reports also analyze why reported results differ from expected results.

Activity, control, and analysis reports answer the following questions about internal activities: what's happening; is it good or bad; and why is it happening. This categorization combined with the key word analysis provides suitable knowledge to determine the quality of the report on a preliminary basis. The key words also define the purpose of the report.

Finally, the flow is analyzed by the producer and receiver codes. These codes are based on the person's level in the organization and the functional area in which the manager works.

The next step in the approach is the evaluation of the effectiveness between the personnel who manage the information flow rationalization process and the generators and users of information. In a large shipyard, survey responses and interviews with managers are effective and minimize the disruption of regular activity. In any case it is vital to bring experience and management judgment to the task. The interviews focus on how the information is used, how appropriate the level of detail is, and the time consumed in using the information.

At this point in the process, a plan of action for the marine organization can be developed. The plan of action must be specific and must be implemented by shipyard management. It is useful to explain the reasons for the actions and the impact of the actions in terms of quality and efficiency to gain organizational commitment for the modifications.

The final step in the process is implementation which follows the following types of actions:

- report elimination
- distribution reduction
- combination of overlapping or redundant reports
- report format design
- development of management summary reports to replace other reports
- on-line rationalization of computer data gathering instead of printed reports.

This last action triggers a separate set of discussions concerning office automation, office of the future concepts, and microcomputers, Hopefully, the industry will continue to invest in automated information transferral.

EXPECTED BENEFITS OF RATIONALIZATION OF INFORMATION FLOWS

Having summarized an approach to rationalization of information flows, what can a shipyard expect to gain from such an exercise? There are four primary results:

- Reduced volume of paper--for a reprensentative client, the number of pages of reports were reduced by 40 percent on a yearly basis.
- Reduced information costs--for this same client, the annual savings in paper, line printing and distribution effort exceeded $500,000. This savings estimate does not include the savings in management time, time which can now be devoted to more effective performance of the job responsibilities.
- More effective reports--the support structure of the company aligns with the management structure to make the management process more efficient and improve decision-making,

- More efficient use of management resources--by avoiding information overload and supporting managers with the information they need, management decisions, responses, and actions are performed more efficiently and accurately.

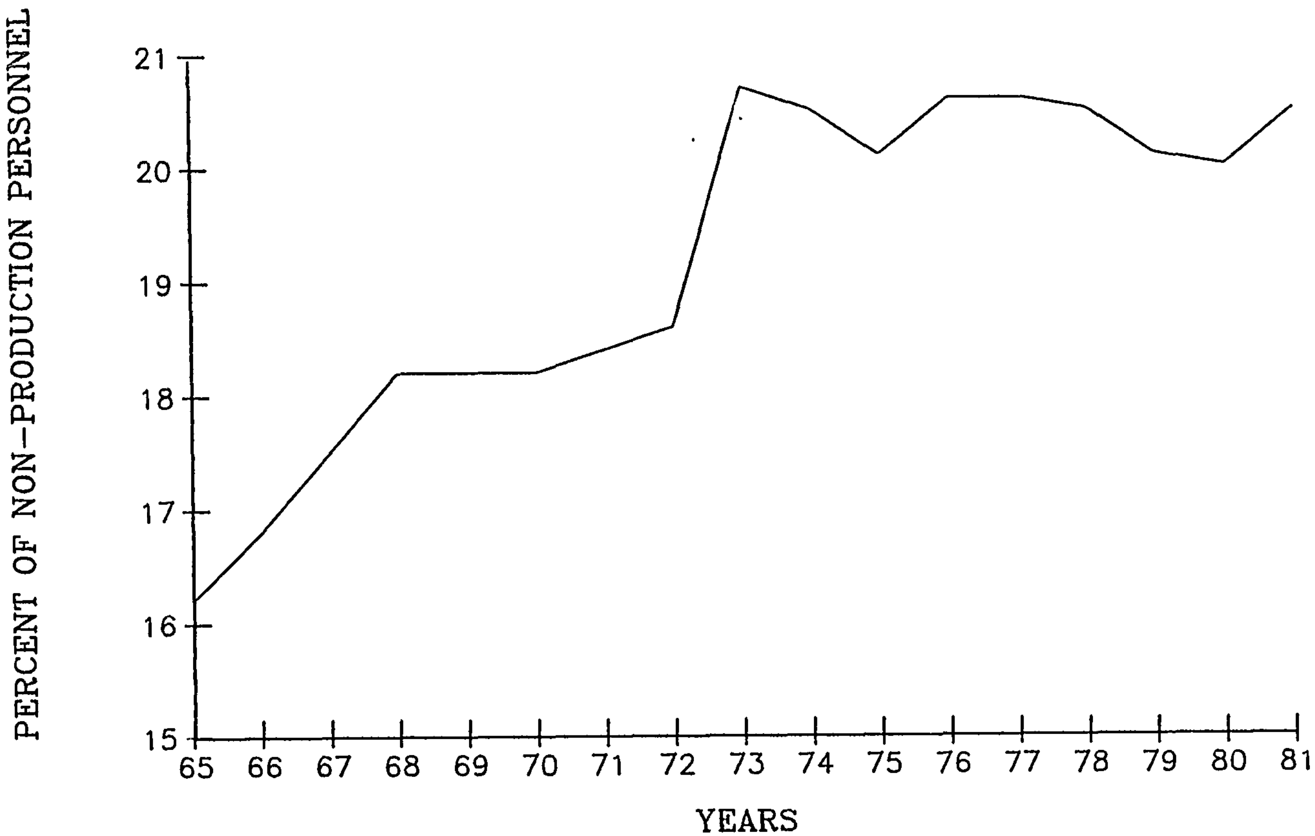
It is important to recognize that the flow of information within a shipyard is only one element of the productivity challenge that faces U.S. shipbuilders and repairers. The value of quality information can be undermined by a poor organizational structure or by inferior management personnel just as the best management organization can be undermined by deficient information flows.

Management of information deserves shipyard management attention and commitment because the process and the results strengthen the organization and increase the effectiveness of the individuals that comprise it. Although the process may be regarded by some as less critical than production oriented investments of time and capital, it may yield a higher return.

Capital investments may enable a company to innovate, gain market share, respond to customers* needs, and improve the quality of products or services, but these improvements are not the same as productivity gains. Nationally, capital investments result in productivity gains of only 1 or 2 percent. Rationali.-zaton of information flows within an organization can result in sigificant productivity gains as well as complementing gains from other actions.

EXHIBIT 1

COMPARISON OF NON-PRODUCTION PERSONNEL TO TOTAL SHIPBUILDING PERSONNEL



SOURCE: U.S. DEPARTMENT OF COMMERCE, BUREAU OF THE CENSUS.

POST-PROCESSORS FOR THE SHIP HULL CHARACTERISTICS PROGRAM
FOR CALCULATING METACENTRIC HEIGHT

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Washington, D.C.

Mr. McNaull's work experience has been with the Department of Naval Architecture in Berkeley, Germanischer Lloyd in Hamburg, West Germany, D. J. Seymour in San Francisco, and the Maritime Administration in Washington,D.C. In his current position as a Computer Specialist at the Maritime Administration he is working on computer-aided ship design and analysis.

Mr. McNaull holds a B.S. degree in Ocean Engineering from Florida Atlantic University, a M.S. degree in Naval Architecture from University of California, Berkeley, and is working on a D.Sc. degree in Structural Engineering at George Washington University.

Post-Processors for the Ship Hull Characteristics Program for Calculating Required Metacentric Height

1. Abstract

Intact and damaged stability analyses require significant calculation effort beyond determining a righting arm curve for one operating or damaged condition. A required metacentric height (GM) curve for all operating conditions is usually the desired final result. A set of post-processing subroutines have been developed by the Engineering Computer Group at the Maritime Administration to permit direct calculations of the required metacentric height in an intact operating condition or in a damaged condition. These subroutines allow evaluation of intact and damaged stability of a vessel using the U.S. Coast Guard's, the Maritime Administration's or the International Maritime Organization's stability criteria.

2. Introduction

In 1980 and 1981 IREAPS in cooperation with industry and Government wrote the specification for a new hull scientific program to replace the U.S. Navy's Ship Hull Characteristics Program (SHCP). The new hull scientific program is to have expanded capabilities, one of which is post-processors for the intact and damaged stability subroutines. The righting arm curve calculated by the intact or damaged stability subroutines is the input to the post-processor subroutines and a minimum metacentric height (required GM) which satisfies various regulatory body requirements the output.

The post-processors consist of separate FORTRAN subroutines for each of the stability criteria to be satisfied. They were written by the Engineering Computer Group at the Maritime Administration, U.S. Department of Transportation. Several of the subroutines are incorporated into the current version of SHCP and the rest exist presently as stand-alone programs. For ease of use; all of the subroutines are being incorporated into SHCP until the new hull scientific program is available, at whichtime they will be incorporated into that program.

In what follows, the procedures for calculating the required GM for each stability criteria will be described. The various intact and damaged stability criteria contained in the 1981 computer program specification will be restated. Finally some example calculations on actual ships will be presented.

3. Background

Before describing the stability criteria contained in the specification for the new hull scientific program, it may be worthwhile to mention briefly why this stability analysis is necessary and how it is done. A ship must safely survive the worst sea and weather conditions in the areas of operation and must be able to survive prescribed amounts of damage to the hull. And so stability requirements written by the regulatory bodies must be satisfied. To check all the applicable stability requirements for all loading conditions requires rather extensive calculations.

For <u>intact</u> stability, a hull scientific program is used to generate intact righting arm curves over a range of heel angles for a range of drafts, trims, and vertical center of gravities. Each draft and its' associated trim and KG gives one righting arm curve. Various departure, intermediate, and arrival conditions may be considered to determine which draft, trim, and KG combinations to check. The full range of operational drafts must be included. Each righting arm curve and the KG at which it was calculated is input into the post-processor sub-routines which calculate one limiting KG for each of the applicable intact stability criteria. Then the lowest of the limiting KG values is selected as the maximum allowable KG for the draft. The righting -arm curve for the next draft is input to the post-processor subroutines and the procedure is repeated. The points are plotted as draft versus maximum allowable KG which gives a "maximum KG curve". Or maximum KG may be converted to manimum GM, which gives "required GM curve". If damaged stability must be considered too, then the intact required GM curve must be plotted with the damaged required GM curve and the largest of two values selected at each draft and plotted.

For <u>damaged</u> stability, again a hull scientific program is used to calculate righting arm curves and draft and trim over a range of heel angles for several damaged conditions and a range of initial drafts and for one assumed KG. Each damaged condition and initial draft pair gives one righting arm curve: The damaged conditiions which are expected to give the worst sinkage, heel, and trim are all identified and investigated. Each damaged righting arm curve and the KG at which it was calculated is input into the post-processor subroutines which

calculate one limiting KG for each of the applicable damaged stability criteria. Typically one decides from the outset which criteria is most severe (i.e., MARAD one compartment or USCG two compartment for tankers). For each damaged condition and initial draft, the lowest of the limiting KG values is selected as the maximum allowable KG and this is repeated for the other initial drafts. Thus a curve of draft versus maximum allowable KG is plotted for the damaged condition. If several damaged stability criteria apply, each of these curves of draft versus maximum allowable KG is really an envelope of the smallest KG for each of the stability criteria for that damaged condition. This procedure is repeated over the range of initial drafts for the other damaged conditions, giving a series of curves. The smallest value at each draft is selected as the envelope of the curves and this gives the maximum KG curve for damaged stability. (See Figure 1) The maximum KG curve is often converted to a required GM curve. (See Figure 2) Either the maximum KG curve or minimum GM curve is included in a ship's stability booklet and the ship's master makes certain that in all operating conditions the GM is equal to or greater than the value on the curve.

We will have need of a few stability equations in the following discussion. The first equation is used to find the limiting KG given a righting arm curve calculated at some assumed KG and given a limiting heel angle. Note that this equation is used to determine the limiting KG for only two damaged stability criteria. For other criteria, the method of determining limiting KG will be described later.

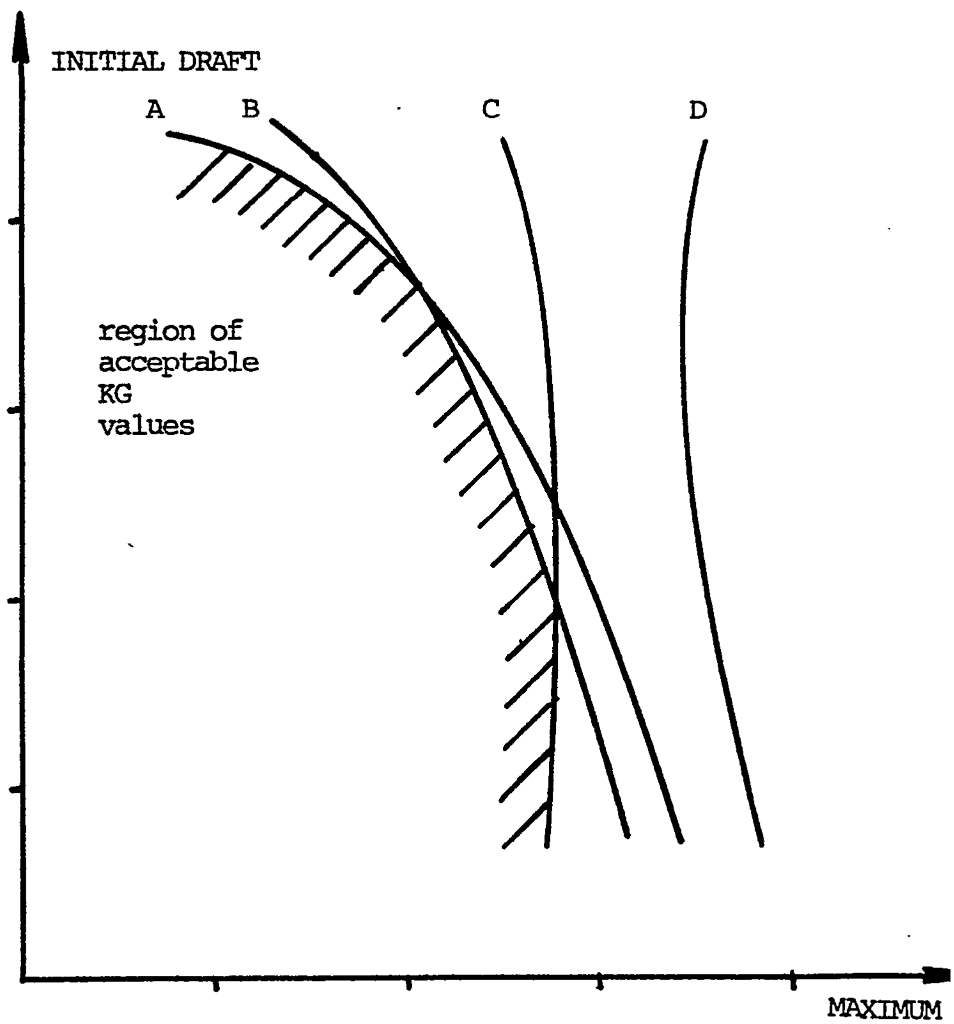


FIGURE 1. Maximum KG Curve

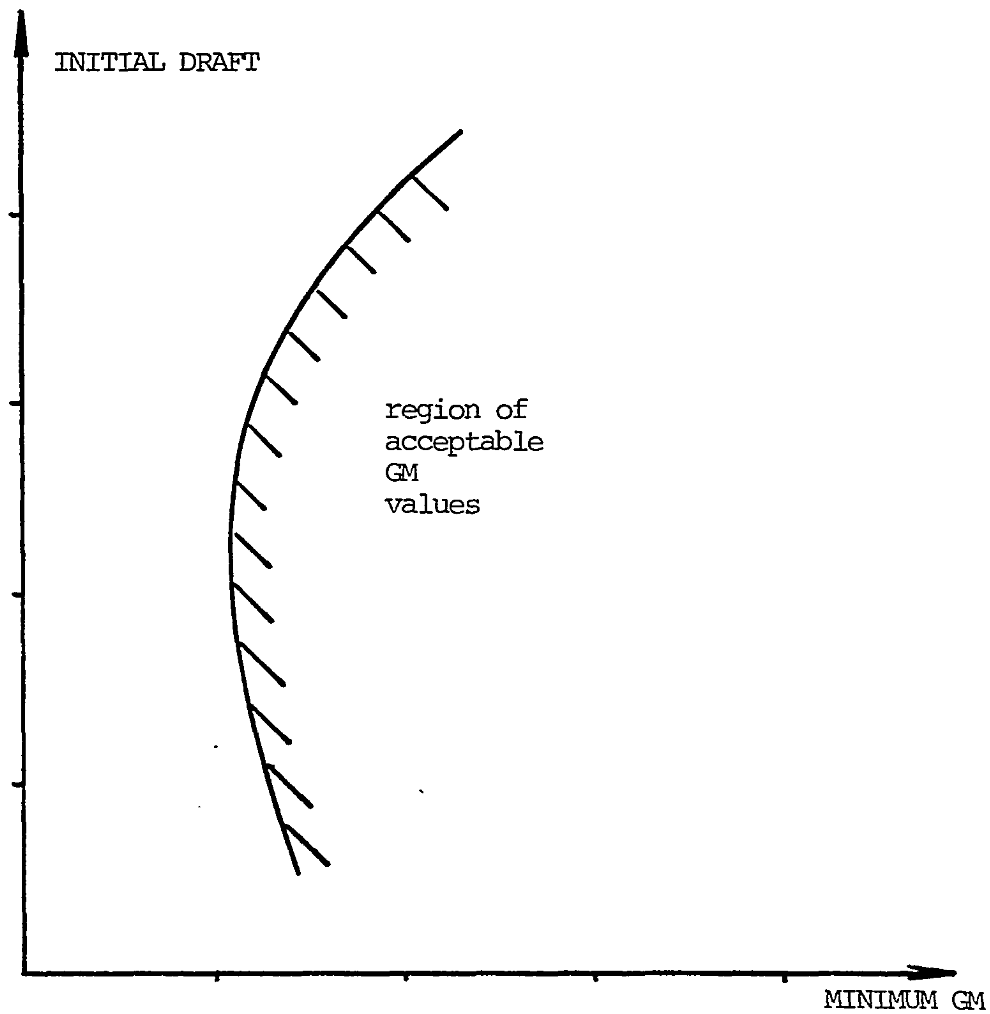


FIGURE 2. Minimum GM Curve

(1) $KG = KG + \frac{GZ}{\sin\theta}$

where KG = limiting vertical of gravity

KG; = initial assumed vertical center of gravity

θ = the limiting heel angle (specified by a stability criteria)

GZ_0 = the righting arm at heel angle θ calculated for assumed vertical center of gravity KG,.

Once the limiting KG is determined by equation (1) or some other method, the original righting arm curve which was calculated for an assumed KG is corrected using the following stability relationship.

(2) $GZ_* = GZ_o - \overline{OG}\sin\theta$

where GZ_* = corrected righting arm for limiting KG

GZ_0 = initial righting arm calculated for assumed KG

θ = heel angle

$\overline{OG}$ = limiting KG - assumed KG

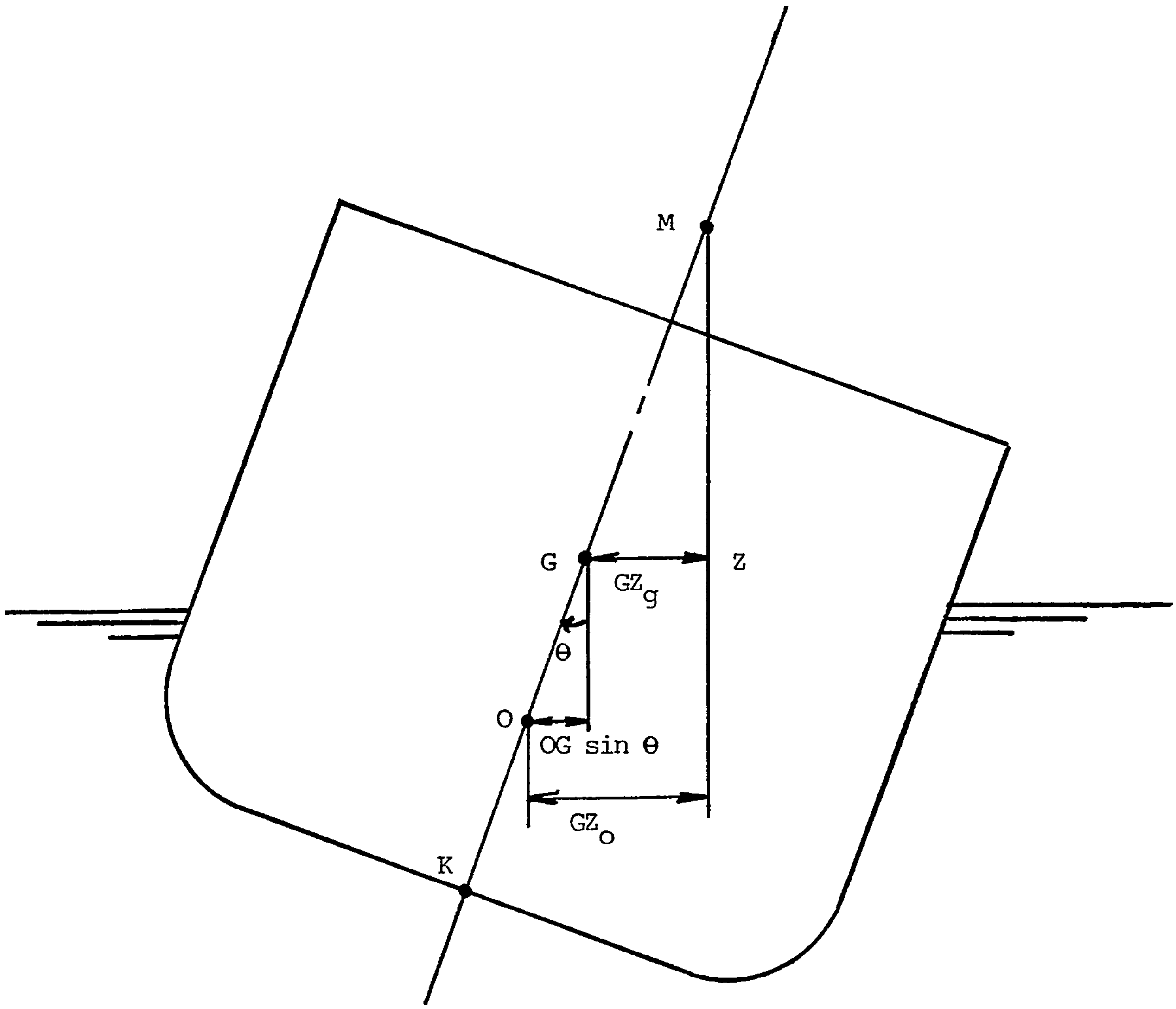
= vertical shift of center of gravity

(See Figure 3.)

From equation (2) it can be seen that an increase in KG reduces the righting arm. Conversely a decrease in KG increases the righting arms. (See Figure 4.) Vertical center of gravity can be converted to metacentric height using the relationship.

(3) GM = KM - KG

Often a minimum GM curve is plotted instead of a maximum KG curve, so



K = keel
0 = initial position of center of gravity
G = shifted position of center of gravity
M = metacenter

FIGURE 3. Change in Righting Arm with Vertical Shift of Center of Gravity

equation (3) is used.

In equation (2) the heel angles θ and the righting arms GZ are calculated by a hull scientific program at the assumed KG. The limiting KG's are then determined according to each applicable stability criteria by the post-processing subroutines. The applicable stability criteria depend upon the ship type and are specified in regulations published in the Code of Federal Regulations by the U.S. Coast Guard in the United States, and by other regulatory bodies in other countries. The smallest of the limiting KG values for all the applicable stability criteria is the maximum allowable KG for that particular intact or damaged condition.

4. Stability Criteria

The following stability criteria for both intact and damaged stability are to be included in the new hull scientific computer program. This is not an all inclusive list of stability criteria, but it does represent the most commonly used stability criteria for commercial ships.

The new computer programs calculate the limiting KG's which satisfy each of these criteria. At this writing, not all of the subroutines are merged into the current version of the Ship Hull Characteristic Program. Work is in progress to merge them into SHCP until the new hull scientific program is available at which time they will be merged into that program.

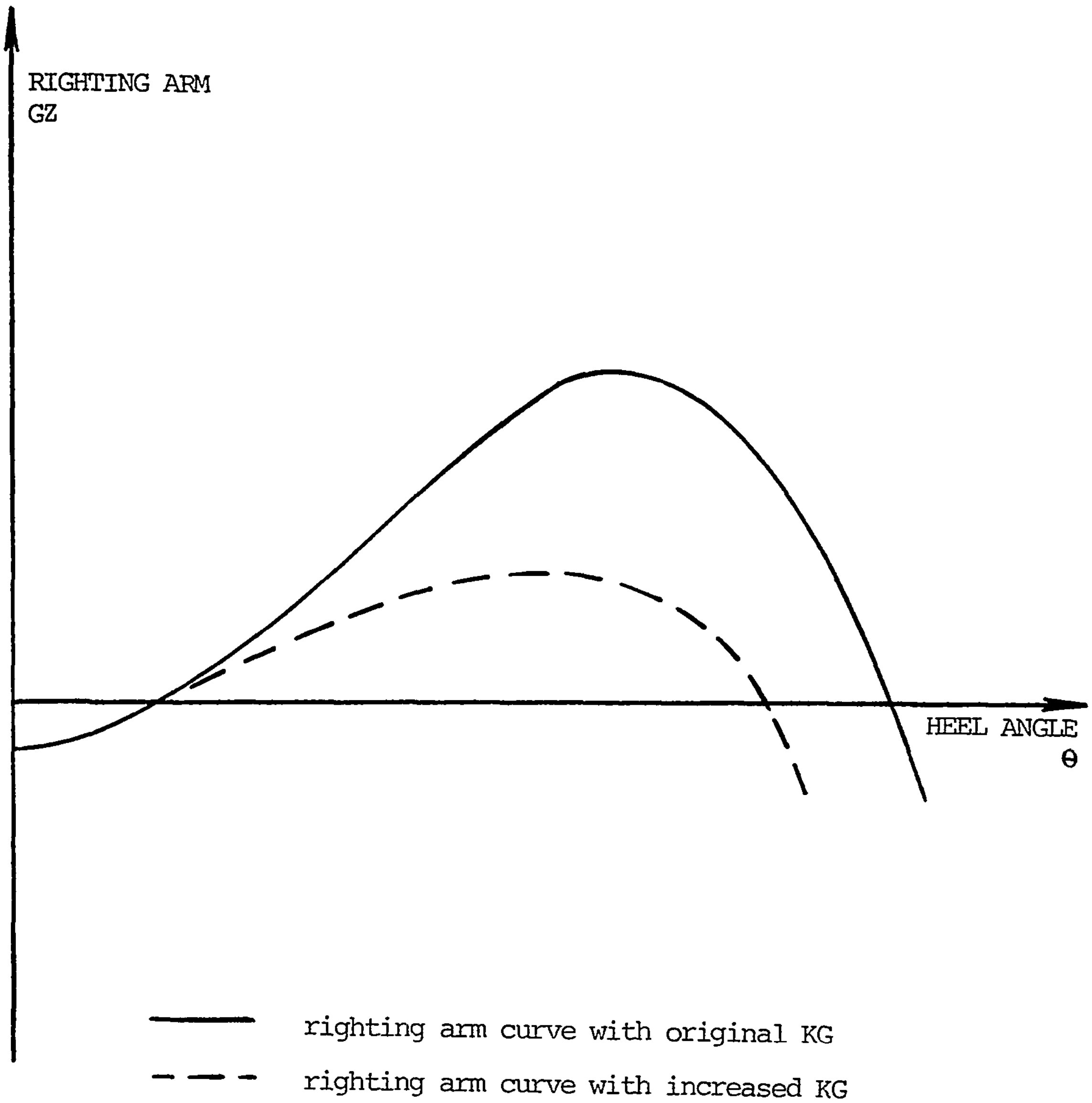


FIGURE 4. Reduction in Righting Arm Due to Increase in KG

4a. Immersion of Downflooding Points and/or Margin Line

Checking for downflooding points immersion and/or margin line immersion is required by most of the damaged stability criteria. The subroutines for these calculations are merged into the damaged stability subroutine of SHCP. If the stability criteria requires that both downflooding points and margin line be considered, then the lowest downflooding point or the lowest margin line point after sinkage, heel, and trim is taken as the one which limits. For symmetrical damage, only zero degrees heel is considered. The approach taken in finding the solution depends on the ship length because of the fact that KG effects trim only if the vessel is small - say less than 200 feet. The combination of sinkage and trim at zero degrees heel determines when the lowest downflooding point and/or margin line point is just tangent to the damaged waterline. The damaged condition, i.e. the compartments considered, effect both draft and trim. But KG effects only trim and only if the vessel is small.

For symmeterical damage of small vessels, the user must iteratively rerun SHCP incrementing the assumed ~~KG un~~til the lowest down-flooding point or margin line point is just tangent to the damaged waterline. The KG at which this occurs is the limiting KG for immersion criteria for the damaged condition. The same procedure is repeated for other symmetrical damaged conditions. If the immersion criteria is satisfied only by very small KG values (or perhaps even negative KG values), this indicates that

there is insufficient reserve buoyancy for the damaged condition being considered and that changes to the bulkhead spacing are required.

For symmetrical damage of large vessels, only one run of SHCP is required since KG essentially has no effect on trim. So a damaged condition satisfies immersion criteria or does not for all practical KG values. If the damaged condition satisfies immersion criteria then the maximum allowable KG depends on other stability criteria. If immersion criteria is not satisfied, then this indicates that there is insufficient reserve buoyancy for the damaged condition being considered and that bulkhead spacing must be changed.

For unsymmetrical damage, only one run of SHCP is required for each initial draft and for each damaged condition investigated, but with a range of input heel angles--say from 0 degrees to 60 degrees. From the final attitude of the vessel (sinkage, heel, trim) at each of the input heel angles, the relative position of the lowest downflooding point or margin line point is determined relative to the damaged waterline. If the input heel range is great enough, then at some heel angle the lowest downflooding point or margin line point will be just tangent to the damaged waterline. The heel angle where this occurs is interpolated by the program and it is the damaged downflooding heel angle for the damaged condition. Then the maximum KG can be calculated from equation (1) where:

KG = maximum vertical center of gravity for margin line and downflooding point criteria

KG_i = the assumed vertical center of gravity used for calculating the righting arm curve

θ = the damaged downflooding heel angle

GZ_θ = the righting arm at heel angle θ calculated for vertical center of gravity KG_i

The same procedure is repeated for the other initial drafts. Then the limiting KG for this criteria is compared with the limiting KG for the other applicable stability criteria at each draft. The smallest of the limiting KG's at each draft is selected and plotted as one curve over the range of initial drafts. This procedure is repeated for the next damaged conditions over a range of initial drafts, until all the damaged conditions are investigated. The maximum KG curve is the envelope of the smallest KG of all damaged, conditions at each draft.

4b. <u>Area Criteria</u>

For an intact (undamaged) ship, there are several stability criteria which specify that the area under a righting arm curve between specified intergration limits must be equal to or greater than a specified value. At this writing, these calculations are done by a separate post-processor program that is not yet merged in SHCP.

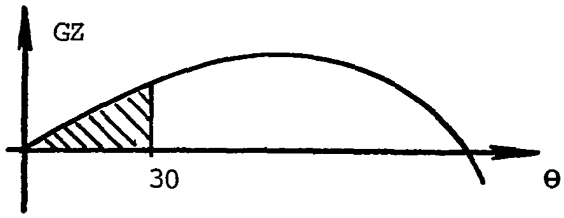
For each area criteria the user specifies the integration limits

and the desired area under the righting arm curve between the integration limits. The program calculates the limiting KG that satisfies the area requirement by iteratively shifting KG up or down, correcting the righting arm curve for the new KG, and integrating to determine the area under the curve between the specified limits. The KG and area are stored for each iteration. The KG which gives the desired area is interpolated from the stored values.

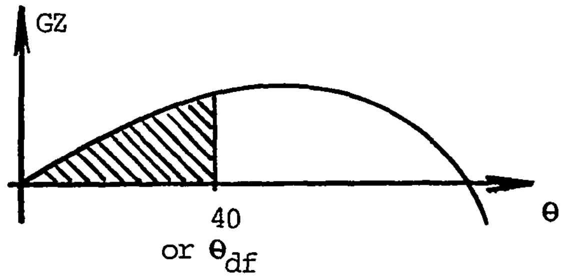
Figure 5 shows typical area criteria for which the limiting KG can be calculated by the post-processor program. Note in the figures that for a symmetrical ship the intact statical stability heel angle is zero degrees. For an unsymmetrical ship, the intact statical stability heel angle is non-zero, however, the same calculations would apply but with the lower integration limit that statical stability heel angle instead of zero degrees.

For each specified area criteria the post-processor program first calculates the static stability heel angle, the heel angle at maximum righting arm, and the diminishing stability heel angle to determine the integration limits which are not given directly in degrees. One maximum KG is determined for each area criteria specified. The smallest of the KG's is the limiting KG for area criteria and it must be compared to any other stability criteria that apply. The smallest KG value from all the criteria is the maximum allowable KG for that particular load condition. The procedure is repeated for other load conditions to develope the

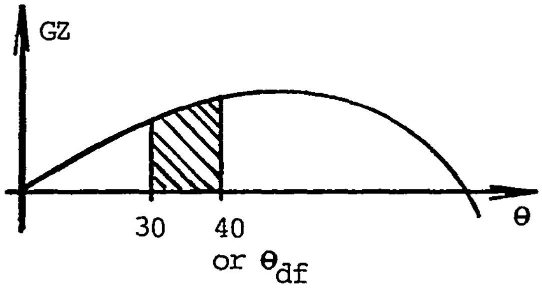
area between 0 and 30 degrees



area between 0 and 40 degrees or angle of downflooding θ_{df} whichever is less



area between 30 and 40 degrees or θ_{df} whichever is less



area between 0 degrees and angle at maximum righting arm

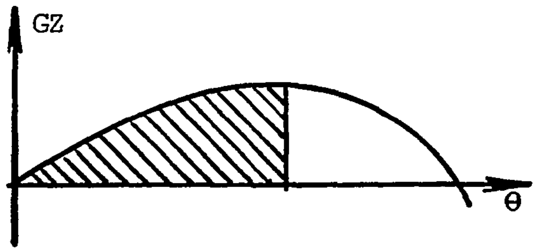


FIGURE 5. Intact Stability Area Criteria

maximum KG curve over the range of operation drafts.

The next three stability criteria (4c, 4d, and 4e) apply to damaged ships. The post-processing subroutines which do these calculations currently exist in a separate program. They are being integrated into the current Ship Hull Characteristic Program until the new hull scientific program is available.

4c. Static Stability Heel Angle Criteria

For certain vessel types, a ship with unsymmetrical damage must have a static stability heel angle equal to or less than a specified value. For example, for cargo ships built in the U.S. and U.S. passenger ships the static stability heel angle must be less than 15 degrees. (See Figure 6) Note that this criteria does not apply to ships with symmetrical damage since the static stability heel angle would always be zero.

Here the solution can be obtained without resorting to iteration. The KG which gives the required static stability heel angle is determined from equation (1) where

KG = limiting vertical center of gravity

KG_i = assumed vertical center of gravity

θ = the desired static stability heel angle

GZ_θ = the righting arm at angle θ calculated for vertical center of gravity $\overline{KG}$,

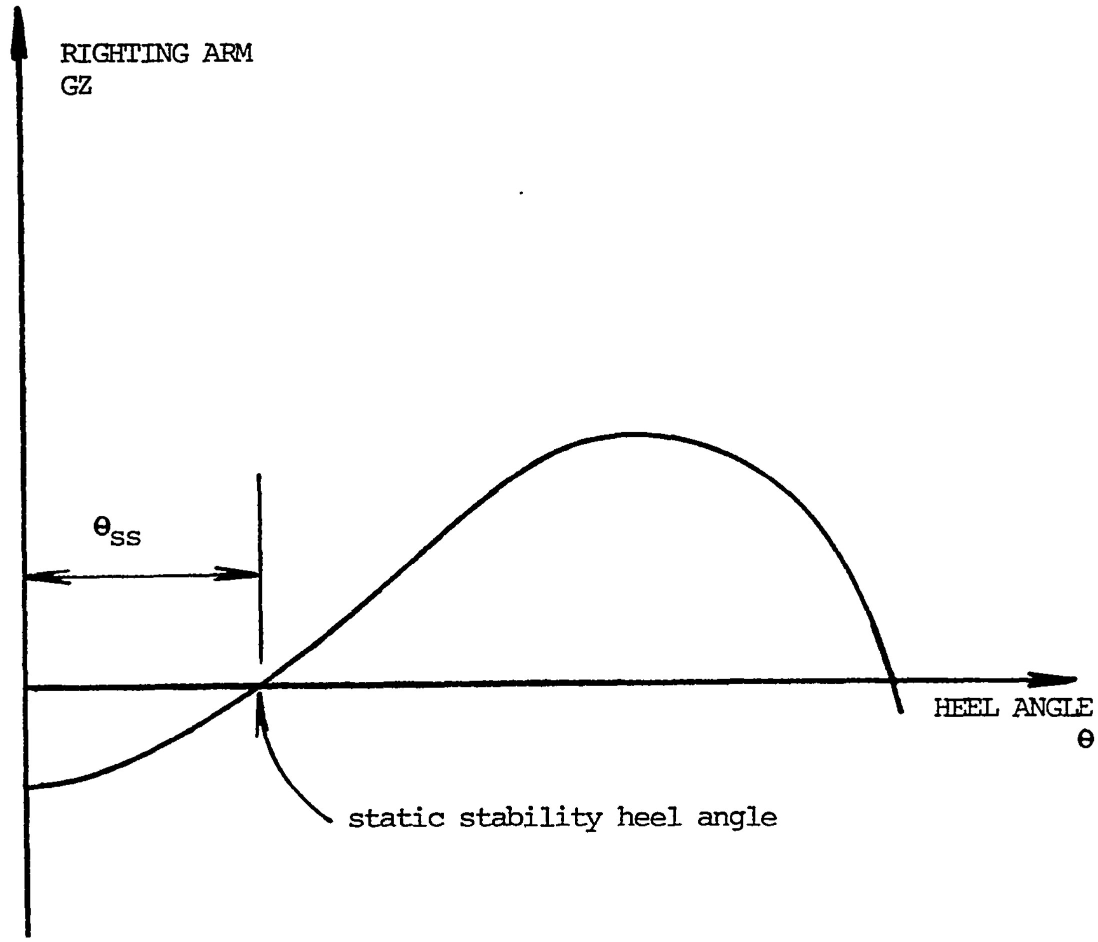


FIGURE 6. Static Stability Heel Angle Criteria

4d. Range of Positive Stability Criteria

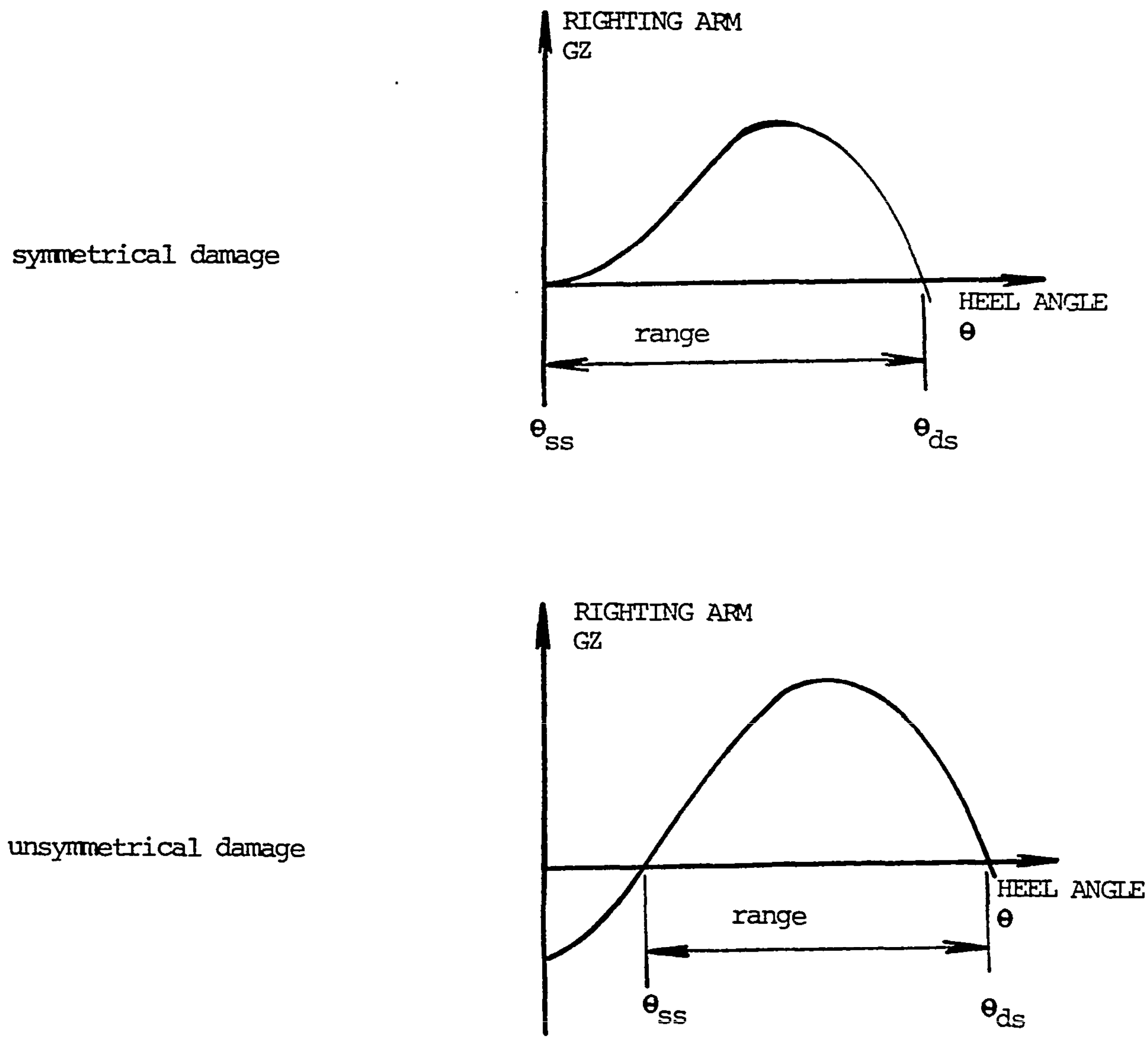
This criteria applies to both symmetrical and unsymmetrical damage. The damaged ship must have a range of positive stability equal to or greater than a specified value. The range of positive stability is defined as the positive righting arms between the static stability heel angle and the diminishing stability heel angle. Tankers, chemical carriers, and LNG ships must satisfy this criteria and the range must be 20 degrees. (See Figure 7)

Here the limiting KG is determined iteratively. The range is determined as the KG is shifted up or down by solving for the static stability and diminishing stability heel angles, then taking the difference.. The KG and the range at this KG are stored in arrays for each iteration. The KG versus range values are interpolated at the required range to give the limiting KG.

4e. Maximum Righting Arm Criteria

Two separate stability criteria have requirements which involve the maximum righting arm. The first criteria specifies that the magnitude of the maximum righting arm must be at least a certain value. This one applies to both symmetrical and unsymmetrical damage. It is also an intact criteria for some vessels, such as vessels of unusual proportion and form. (See Figure 8)

We start with a damaged righting arm curve for an assumed KG and



θ_{ss} = static stability heel angle

θ_{ds} = diminishing stability heel angle

FIGURE 7. Range of Positive Stability Criteria

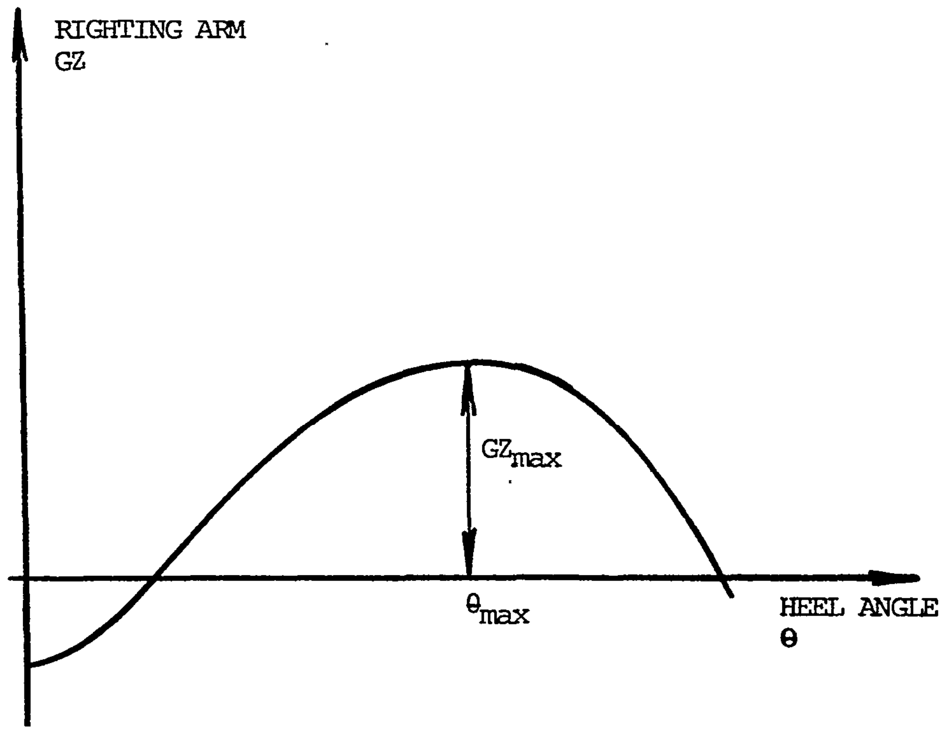


FIGURE 8. Maximum Righting Arm Stability Criteria

initial draft and for one damaged condition. For this criteria the limiting KG is determined iteratively. The KG is shifted up or down and the magnitude of the maximum righting arm is evaluated. The KG and the maximum righting arm at this KG are stored in arrays for each iteration. These stored values are interpolated at the maximum righting arm required by the criteria to give the corresponding limiting KG. Then this limiting KG is compared to the limiting KG for other stability criteria for the same damaged condition and the smallest value is selected for each of the initial drafts investigated. And so one curve is drawn of draft versus limiting KG for each damaged condition and that curve satisfies all the stability criteria that apply. The procedure is repeated for all other damaged conditions.

Another stability criteria which involves maximum righting arm specifies that the maximum must occur at an angle of heel not less than a specified value. This is an intact stability criteria. The procedure for calculating the limiting KG which satisfies this criteria is similar to the procedure above, except that instead of magnitude of the maximum righting arm the location of the maximum righting arm is considered. That is, the heel angle where the maximum righting arm occurs is considered.

5. Conclusions

Several intact and damaged stability criteria have been briefly described, along with the procedure for calculating the limiting KG which satisfies the criteria. Computer subroutines have been written by the Engineering

Computer Group, Maritime Administration, U.S. Department of Transportation to do these particular calculations. At this writing not all of the subroutines are incorporated into the current version of the Ship Hull Characteristic Program. However, this is being done until the new hull scientific program is available.

The object of developing these new subroutines is to save shipyards, design agents, and Government agencies time and money. And to have one standard program that is verified, documented, and kept up to date. In a typical commercial ship design, the naval architects might investigate 5 to 10 intact and damaged conditions at 3 to 4 drafts for 4 to 8 intact and damaged stability criteria. That is, a total of 60 to 320 calculations may go in producing one final required GM curve, at a cost of about $100 to $1,000 for computer time and about $800 to $2,500 for the naval architect. Clearly some automation would be helpful since so many calculations are involved. If there is anyone here who is still using a planimeter to integrate righting arm curves, these subroutines may be of interest to you.

6. Acknowledgements

The author would like to thank Mr.Freddie Johnson, Chief of the Engineering Computer Group at the Maritime Administration, for his support and encouragement throughout the long period of time required for this work and Mr. Geoffrey Fuller, the Maritime Administration's expert on stability of vessels, for the many technical discussions on damaged and intact stability criteria.

APPENDIX I

Examples of Computer & Plotter Output

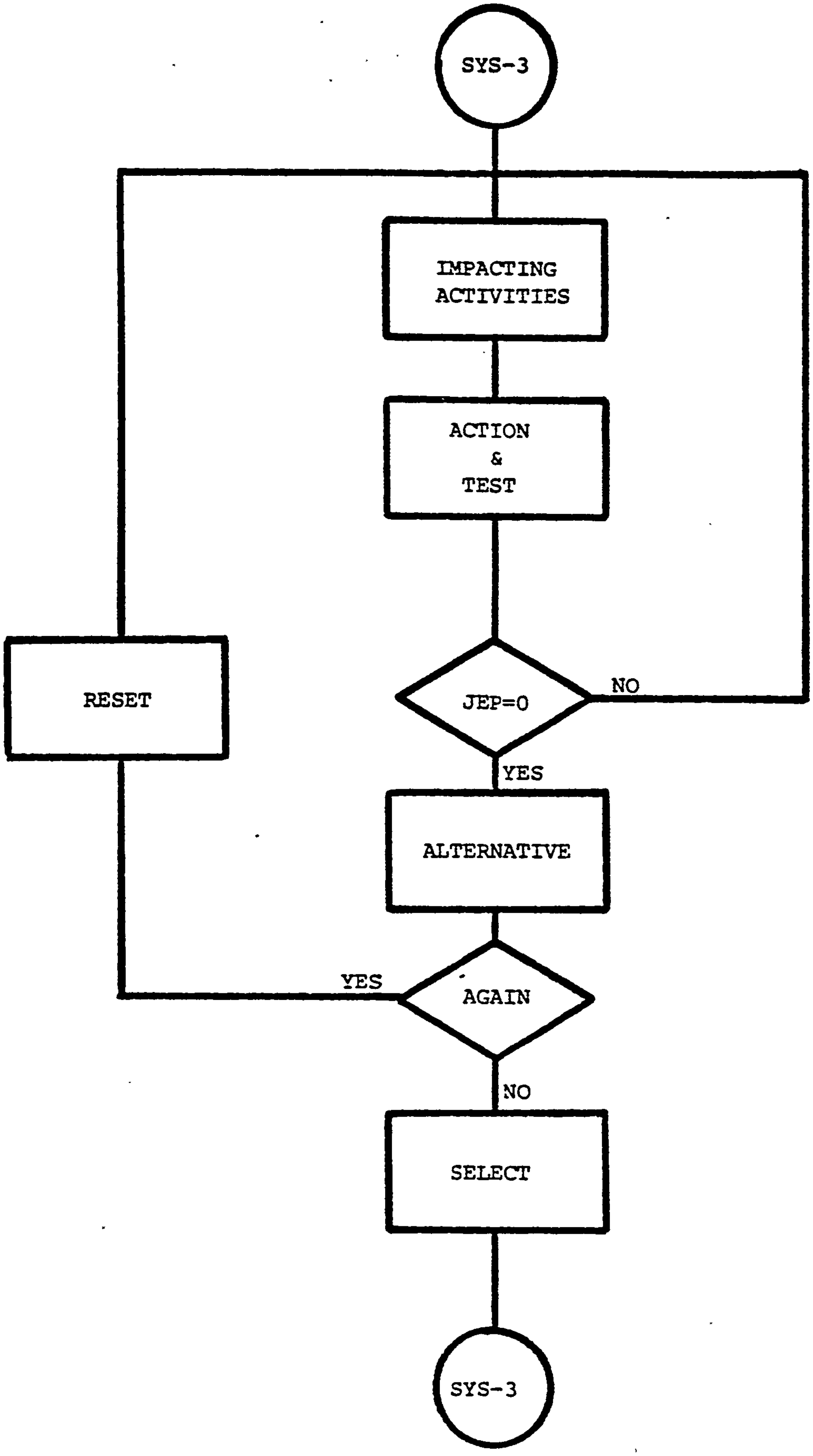
This section contains examples of the following:

1a. Intact Stability Area Criteria

1b. Damaged Stability Maximum Righting Arm,
Static Stability Heel Angle, and
Heel Range Criteria

1c. Damaged Stability Immersion Criteria

However, the quality of the resulting reproduction of the plot copies submitted were illegible and thus are not included in these prceedings. Readers interested in obtaining copies of this appendix should contact the author.


SYS-3
IMPACTING ACTIVITIES
ACTION & TEST
JEP=0
NO
YES
RESET
ALTERNATIVE
YES
AGAIN
NO
SELECT
SYS-3

STATE-OF-THE-ART CAD/CAM APPLICATIONS IN THE SHIPBUILDING INDUSTRY

R. L. Diesslin
Research Institute
IIT Research Institute

Richard L. Diesslin has nearly 10 years of experience in structured analysis and conceptual modeling, industrial management, group technology, and the development of computer aids and simulation tools for production planning, evaluation, and scheduling. He is presently involved with the state-of-the-art review to define the "to-be" architecture for the aerospace factory of the future (ICAN 1105). Previous ICAM work includes structured analysis models for the Air Force Integrated Planning System (IPS), the Integrated Center (ICENT), and Manufacturing Control-Materials Management (MC-MM). Mr. Diesslin has recently completed a comprehensive study to develop a conceptual data base design model for outfit planning in shipbuilding, which details the required functions, information requirements, and data relationships. He has also contributed to a technoeconomic feasibility study of numerical control (NC) machining applied to complex molds, and has provided technical and financial management consulting to firms affected by foreign imports.

ABSTRACT

This paper discusses the National Shipbuilding Research Program's comprehensive study of CAD/CAM applications in the shipbuilding industry. The project is funded by the Maritime Administration and is being performed by IIT Research Institue in cooperation with the **Institute** for Research and Engineering for Automation and Productivity in Shipbuilding **(IREAPS) and the Ship** Production Committee's SP-4 Panel on Design/Production **Integration.**

The project has as its goals:

(1) To identify and compile present uses of CAD/CAM in the design, manufacturing and production of ships in the United States.

(2) To identify gaps in U.S. shipbuilding CAD/CAM technology applications with respect to a shipyard functional breakdown.

(3) To locate and recommend advanced CAD/CAM resources for application to deficient areas in U.S. shipbuilding.

These goals are being accomplished through the use of a comprehensive computerized literature search, a detailed shipyard questionnaire, shipyard visits, and solicitation of CAD/CAM vendor information. In all, 46 specific computer and automation technologies are being studied as they are applied in industry to the numerous shipyard functions. The current level of integration of these technologies is also being investigated.

COMPUTER AIDED DESIGN

BENEFITS	PROBLEMS
* STANDARDIZATION	* INTEGRATION
* PRODUCT QUALITY	* SOFTWARE
* LEADTIME	* SUPPORT PERSONNEL
* PRODUCIBILITY	* IMPLEMENTATION
* PRODUCTION PRODUCTIVITY	* USER SKILL

INCREASE OF PRODUCTIVITY BY AUTOMATED PREFABRICATION OF PIPE SPOOLS

G. Wilkens
President
Oxytechnik Ges. MbH

Mr. Wilkens is the President and was one of the founding members of Oxytechnik Gesellschaft fur Systemtechnik mbH, a subsidiary of Messer Griesheim GmbH in Frankfurt, West-Germany.

Mr. Wilkens studied mechanical engineering at the Technical University, Hannover, West-Germany, where he gained a masters degree and then went on to study for his welding engineer's qualification.

ABSTRACT

I. Automatic Pipe Processing System

A. Actual situation
B. Automatic processing and prefabrication opposite to actual methods - examination of productivity increase
C. Higher quality due to mechanized fabrication

II. Conditions of Flow Line Production

A. New philosophy: Work on straight pipes as long as possible - bend last

B. Pipe processing stations

- storing
- cutting
- cleaning
- painting
- bevelling
- welding of slip on and weld neck flanges
- bending

III. Control of Pipe Processing Lines

A. On and Off line controls
B. How to get data for computer input

INCREASE OF PRODUCTIVITY BY AUTOMATED PREFABRICATION OF PIPE SPOOLS

BY GUNTER WILKENS

INTRODUCTION

INCREASE OF PRODUCTIVITY IN PIPE PROCESSING HAS BECOME A MATTER OF INTEREST AFTER REALIZING THAT TRADITIONAL PIPE PROCESSING IS A VERY EXPENSIVE PROCEDURE COMPARED WITH OTHER MODERN TECHNOLOGIES IN SHIPBUILDING INDUSTRY SUCH AS PANEL WELDING, ETC, IN FACT THERE WAS NOT SPENT TOO MUCH MONEY TO IMPROVE PIPE PROCESSING DURING THE LAST DECADES, ON THE OTHER HAND THE DEMAND FOR PIPES IN A SHIP IS CONSIDERABLE, FIG. 1, SO THAT INVESTMENTS SPENT FOR TECHNICAL PROGRESS CAN BE EXPECTED TO PAY ALREADY AFTER A SHORT PERIOD.

OXYTECHNIK, A WEST GERMAN COMPANY, STARTED TO DESIGN PIPE PROCESSING SYSTEMS 12 YEARS AGO, THE RESULT IS A WIDE SCOPE OF EQUIPMENT UTILIZED IN MORE THAN 30 INSTALLATIONS ALL OVER THE WORLD INCLUDING THE U.S.

THE PROCESS.

BASED ON THE TYPICAL DEMAND FOR PIPES IN SHIPS, THE OXYTECHNIK PIPE PROCESSING SYSTEM COMPRISES THE PRE-FABRICATION OF PIPE SPOOLS ON STATIONARY MACHINES IN A DIAMETER RANGE 1” - 12" UP TO SCHEDULE 80 AS A STANDARD, ON THE CONTRARY TO TRADITIONAL PIPE PROCESSING ALL PROCESSES ARE APPLIED AS LONG AS THE PIPES ARE STRAIGHT AND COLD BENDING IS THE FINAL PROCEDURE, THIS INCLUDES 4 ADVANTAGES:

1. AS THE PIPE CAN BE ROTATED, MECHANIZED HIGH-SPEED WELDING CAN BE REALIZED INSURING GOOD WELD QUALITIES,

2, MANUAL FITTING, TACKING, AND WELDING OF ELBOWS ARE AVOIDED,

3, ALL PROCESSING STATIONS ARE CONNECTED BY CONVEYORS INSURING AN OPTIMUM FLOW OF MATERIALS WITHOUT INTERMEDIATE STORAGE AND ADDITIONAL CRANE HANDLING,

4, MECHANIZED PREPRODUCTION OF PIPE SPOOLS REDUCES THE DEMAND FOR SKILLFUL CRAFTSMEN,

SUCH A PROCESSING LINE WILL BE CONTROLLED MERELY BY PUSH-BUTTON TECHNIQUE AT EACH STATION OR DIRECTLY BY THE COMPUTER AS RECENTLY REALIZED FOR HYUNDAI SHIPYARD IN SOUTH KOREA,

THERE ARE VARIOUS STATIONS FORMING A PROCESSING LINE,

FIG, 2 SHOWS A LAYOUT CONTAINING EQUIPMENT SIMILAR TO WHAT AVONDALE SHIPYARDS ARE UTILIZING:

1. THE PIPES ARE STORED IN A PIPE SILO ON DIFFERENT RACKS DIAMETERWISE, IN THIS CASE THERE ARE 4 BLOCKS OF 32 RACKS EACH, THE SILO IS LOADED AND DISCHARGED BY 2 LIFTS ON RAILS,
2. ALL PIPES PASS THE EXTERNAL SHOTBLASTING CABIN,
3. A SHOTBLASTING LANCE CLEANS THE PIPES INTERNALLY,
4. CUTTING TO LENGTH IS DONE BY A BAND SAW, FROM HERE THE PIPES ARE ORDERED BY PUSH-BUTTON FROM THE SILO AND DIRECTED TO THE
5. AUTOMATED FLANGE WELDING MACHINE OR TO THE
6. MECHANICAL BEVELING MACHINE, AFTER WELDING THE
7, MARKING STATION FOR PRINTING IDENTIFICATION SYMBOLS ON THE RIM OF THE FLANGES IS PASSED,

8. COLD BENDING ON TWO MACHINES 1" - 4" AND OVER 4" TO 8" IS THE FINAL PROCEDURE,

THE LINE IS OPERATED BY ONLY 6 - 7 OPERATORS AND HAS A DAILY OUTPUT OF 150 SPOOLS AT LEAST,

THE EQUIPMENT

THE SCOPE OF EQUIPMENT INTEGRATED IN A PIPE PROCESSING LINE WILL BE SELECTED IN ACCORDANCE WITH THE DEMANDS OF THE SHIPYARD, TO MEET THE MINIMUM REQUIREMENTS OF THE PROCESS INSURING HIGH PRODUCTIVITY A CUTTING STATION, A PIPE FLANGE WELDING MACHINE AND COLD BENDING EQUIPMENT SUITABLE FOR FLANGED PIPES SHOULD BE INCORPORATED IN A TRANSPORTING SYSTEM, AS A MAXIMUM A WIDE SCOPE OF SUPPLY IS AVAILABLE WHICH WILL BE DEMONSTRATED BY THE FOLLOWING SLIDES,

FIG, 3 SILO ITALCANTIERI
FIG, 4 SILO NOBISKRUG AS 'FEEDING DEVICE FOR PIPES TO THE LINE
FIG, 5 EXTERNAL SHOTBLASTING CABIN
FIG, 6 INTERNAL SHOTBLASTING CABIN
FIG, 7 ARRANGEMENT OF SHOTBLASTING CABINS
FIG, 8 PAINT SPRAYING CABIN, EXTERNALLY AND INTERNALLY, IF REQUIRED
FIG, 9 BAND SAW
FIG, 10 PLASMA CUTTING STATION FOR PIPES EXCEEDING 12" DIAMETER
FIG, 11 LENGTH STOP ELECTRONICALLY OPERATED AND LIFTABLE FOR QUICK ADJUSTMENT DURING CUTTING
FIG, 12 AUTOMATIC WIRE BRUSH MACHINE FOR END CLEANING IN CASE OF PREVIOUS PAINTING

FIG, 13 MECHANICAL BEVELING OF PIPE ENDS AS WELD EDGE PREPARATION IN CASE OF WELD NECK FLANGES, THE TOOL IS GUIDED INTERNALLY FOR ACHIEVING A CONSTANT LAND AS AN IMPORTANT CONDITION FOR MECHANIZED WELDING OF THE ROOT PASS,

FIG, 14 ARRANGEMENT OF THE BEVELING UNIT IN FRONT OF A WELD NECK FLANGE WELDER, DIA. RANGE 2" - 12", WITH INTEGRATED TIG AND MIG WELDING EQUIPMENT,

FIG, 15 WELD NECK FLANGE WELDING MACHINE EQUIPPED WITH A PLASMA WELDING TORCH,

FIG, 16 AUTOMATIC SLIP-ON FLANGE WELDING MACHINE TYPE B INCORPORATED IN ALL MAJOR PIPE PROCESSING LINES SUPPLIED BY OXYTECHNIK. WELDING OF BOTH FLANGES AT EACH PIPE END SIMULTANEOUSLY WITH 4 MIG/MAG WELDING TORCHES, INTEGRATED PIPE FEEDING AND DISCHARGING DEVICE, COMPLETE AUTOMATIC PROCESS AFTER PUSHING “START”,

FIG, 17 AUTOMATIC SLIP-ON FLANGE WELDING MACHINE TYPE HY, COMPLETELY NUMERICALLY CONTROLLED BY COMPUTER, INCORPORATED FLANGE AND PIPE FEEDING DEVICE, PIPE DISCHARGER, NO SETTING UP IS REQUIRED IN CASE OF DIAMETER CHANGE,

FIG, 18 CONTROL DESK FOR HY WELDER, DATA INPUT VIA CASSETTE AS ALTERNATIVE TO THE INPUT VIA MAIN FRAME,

FIG, 19 COLD BENDING MACHINE RANGING UP TO 8" DIAMETER SUITABLE FOR FLANGED AND UNFLANGED PIPES,

PIPE PROCESSING DATA

NORMALLY ALL PIPE PROCESSING DATA ARE SET TO EACH MACHINE BY THE OPERATOR ACCORDING TO A FABRICATION LIST, THE EQUIPMENT ALSO MAY BE CONTROLLED DIRECTLY ON-LINE BY A COMPUTER, WHATEVER SYSTEM IS USED THE OXYTECHNIK PIPE SOFTWARE PROGRAMME (OPS) CALCULATES ALL NECESSARY SETTINGS FOR THE OPERATION OF A PIPE PROCESSING SYSTEM VERY EASILY AND QUICKLY,

COMPUTING OF DATA IS DONE BY A TABLE COMPUTER,

THE OUTPUT OF THE OPS COVERS THE FOLLOWING STATIONS, FIG, 20;

1, SILO

MINIMIZING OF PIPE REMNANTS RESPECTIVELY OPTIMUM DISTRIBUTION OF THE CUT LENGTHS TO THE DELIVERY LENGTHS, THIS CALCULATION ALSO GIVES THE PRODUCTION SEQUENCE,

2, LENGTH MEASURING AND SAWING EQUIPMENT

DETERMINATION OF THE CUT LENGTH UNDER CONSIDERATION OF THE BENDS IN A PIPE SPOOL (ELONGATION BY COLD BENDING),

3, PIPE FLANGE WELDING MACHINE

DETERMINATION OF THE NECESSARY BOLT HOLE ANGLE OFFSET IN CASE OF STRAIGHT PIPE SPOOLS WITH FLANGES ON BOTH ENDS TO BE BENT AFTERWARDS, THE CALCULATION GUARANTEES A CORRECT POSITION OF THE BOLT HOLES AFTER BENDING,

4, COLD BENDING MACHINE

DETERMINATION OF

- FEED-IN LENGTH AND LINEAR DISPLACEMENT BETWEEN TWO BENDS
- ALL BENDING ANGLES
- ROTATION ANGLE BETWEEN TWO BENDS,

ALL DATA ARE PRINTED ON ONE PAGE FOR EACH PIPE SPOOL,

THE INPUT OF ALL NECESSARY PARAMETERS IS EFFECTED IN TWO STEPS,

STEP 1 REQUIRES ALL GENERAL INFORMATION WHICH REFER TO ONE SET OF CONSTANT CONDITIONS:

- PIPE DIMENSION
- BENDING RADIUS
- ELONGATION FACTOR
- LENGTH OF SCRAP CUT
- MINIMUM FEED-IN LENGTH
- MATERIAL
- BORE HOLE QUANTITY
- FLANGE DIMENSION
- CUTTING WIDTH

STEP 2 REQUIRES ALL INDIVIDUAL PIPE SPOOL DATA:

- PIPE IDENTIFICATION NUMBER
- QUANTITY OF FLANGES PER PIPE SPOOL
- ALL COORDINATES X, Y, Z DESCRIBING THE SHAPE OF THE PIPE SPOOL
- QUANTITY OF EQUAL PIPE SPOOLS

ECONOMY

INCREASE OF PRODUCTIVITY IS THE FOREMOST DEMAND IN SHIPBUILDING INDUSTRY, BY TURNING MANUAL WORK TO MECHANIZED AND AUTOMATED OPERATIONS, THE ECONOMY OF PIPE PROCESSING IS INCREASED TREMENDOUSLY,

FIG, 21 DEMONSTRATES TIME SAVINGS BY MECHANIZATION COMPARED WITH TRADITIONAL PROCEDURES, BASED ON THESE SAVINGS PRODUCTION COSTS HAVE BEEN CALCULATED TAKING INTO ACCOUNT PERSONNEL AND OVERHEAD COSTS OF PRODUCING A PIPE SPOOL, FIG, 22, INCLUDED IS SURFACE CLEANING, CUT-OFF, WELDING, AND SPRAY PAINTING, THE SYSTEM IS DEPRECIATED OVER 10 YEARS, MECHANIZED PIPE PROCESSING OFFERS CONSIDERABLE SAVINGS, AS THE DIAGRAM INDICATES,

WHEN THE SYSTEM IS USED AT FULL CAPACITY, WHEN THE WORK LOAD DOES NOT PERMIT THE PIPE PROCESSING PLANT TO BE FULLY UTILIZED 100% OF THE TIME FABRICATION COST IS STILL CONSIDERABLY LOWER, (MANUAL PRODUCTION COST CORRESPOND TO 1oo%),

REGARDING THE FACT THAT 60 - 70% OF ALL PIPES FOR A SHIP RANGING FROM 1" - 12" DIA, CAN BE PREFABRICATED IN A FLOW LINE, THE HIGHLY INCREASED PRODUCTIVITY GUARANTEES A FAST RETURN OF INVESTMENT AND JUSTIFIES THE USE OF A MODERN PIPE PROCESSING LINE,

FLEXIBLE PIPE PROCESSING

WHILE THE SYSTEM DESCRIBED CONSISTS OF STATIONARY MACHINES EXCLUSIVELY, MOVABLE SYSTEMS MIGHT BE HELPFUL FOR REMAINING WORK SUCH AS WELDING BRANCHES, ELBOWS, PIPES TO PIPES, ETC, A MOVABLE PROCESSING SYSTEM ALSO WILL BE USEFUL AT SITE.

TO MEET THESE REQUIREMENTS OXYTECHNIK RECENTLY DEVELOPED A SIMPLE FITTING AND CLAMPING SYSTEM FOR EASY ORBITAL WELDING, FIG, 23, THE EQUIPMENT COVERS THE DIAMETER RANGE FROM 1" - 8" AND CONSISTS OF

- A HANDPIECE
- A SET OF MANDRELS FITTING TO THE HANDPIECE AND TO THE PIPE
- A HYDRAULIC CLAMPING VICE
- A HYDRAULIC AGGREGATE,

THE SYSTEM IS DESIGNED TO FIT AND CLAMP WELD NECK FLANGES AND WELD COLLARS TO PIPES, BRANCHES TO COLD NECKED PIPES AND PIPES TO PIPES, THE HEAVIEST WALL THICKNESS SUCCESSFULLY WELDED IN A BUTT CONFIGURATION

WAS 6, 3 MM APPLYING THE TIG IMPULSE PROCESS, THE NEXT SLIDES SHOW THE EQUIPMENT AND ITS EASY HANDLING IN DETAIL,

FIG, 24 HANDPIECE AND MANDREL
FIG, 25 ARRANGEMENT OF TOOLS AND WORKPIECES
FIG, 26 TOOLS IN A DRAWER OF THE BOX CONTAINING
ALSO THE HYDRAULIC AGGREGATE
FIG, 27 CLAMPING VICE

A COMPARISON OF PROCESSING TIME BETWEEN MANUAL AND ORBITAL TIG WELDING DEMONSTRATES THE SUPERIORITY OF THE SYSTEM, FIG, 28.

SUMMARY

PIPE SHOPS MUST NOT LOOK LIKE FIG, 29. IT WAS TRIED TO DESCRIBE SYSTEMS FOR MODERN PIPE PROCESSING WHICH, UTILIZED IN ALL INDUSTRIAL COUNTRIES, HAVE PROVEN TO BE HIGHLY ECONOMICAL, THE INCREASE OF PRODUCTIVITY MAINLY IS BASED ON TURNING MANUAL WORK TO MACHINE WORK, THUS ACHIEVING

INCREASE OF THROUGHPUT,
REDUCTION OF COSTS,
REDUCTION OF SKILLFUL CRAFTSMEN AND
BETTER QUALITIES,

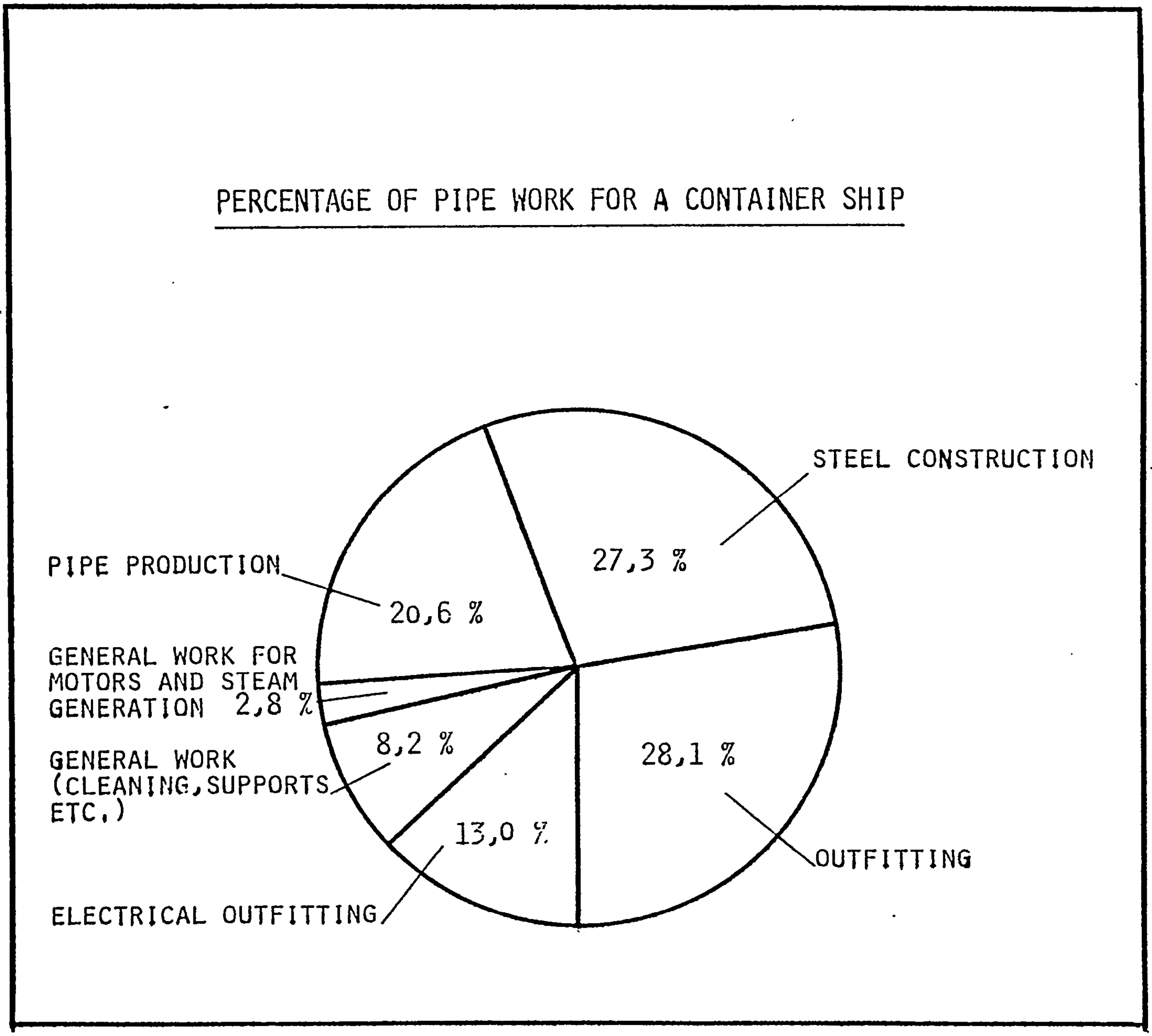

PERCENTAGE OF PIPE WORK FOR A CONTAINER SHIP
STEEL CONSTRUCTION
27,3 %
PIPE PRODUCTION
2o,6 %
GENERAL WORK FOR MOTORS AND STEAM GENERATION 2,8 %
GENERAL WORK (CLEANING,SUPPORTS ETC.)
8,2 %
28,1 %
13,0 %
OUTFITTING
ELECTRICAL OUTFITTING

Figure 1

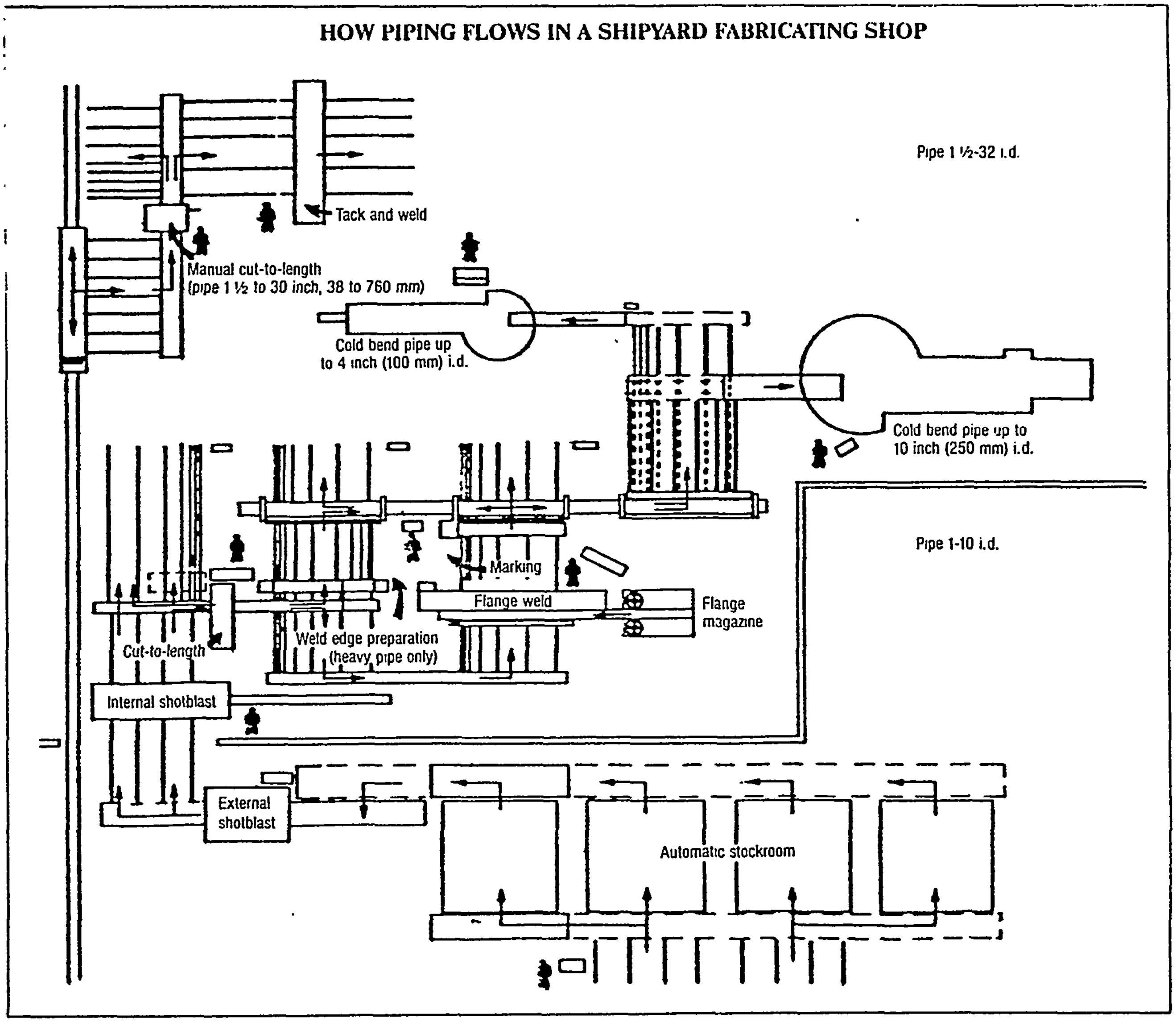

HOW PIPING FLOWS IN A SHIPYARD FABRICATING SHOP
Pipe 1 ½-32 i.d.
Tack and weld
Manual cut-to-length
(pipe 1 ½ to 30 inch, 38 to 760 mm)
Cold bend pipe up
to 4 inch (100 mm) i.d.
Cold bend pipe up to
10 inch (250 mm) i.d.
Pipe 1-10 i.d.
Marking
Flange weld
Flange
magazine
Weld edge preparation
(heavy pipe only)
Cut-to-length
Internal shotblast
External
shotblast
Automatic stockroom

Figure 2

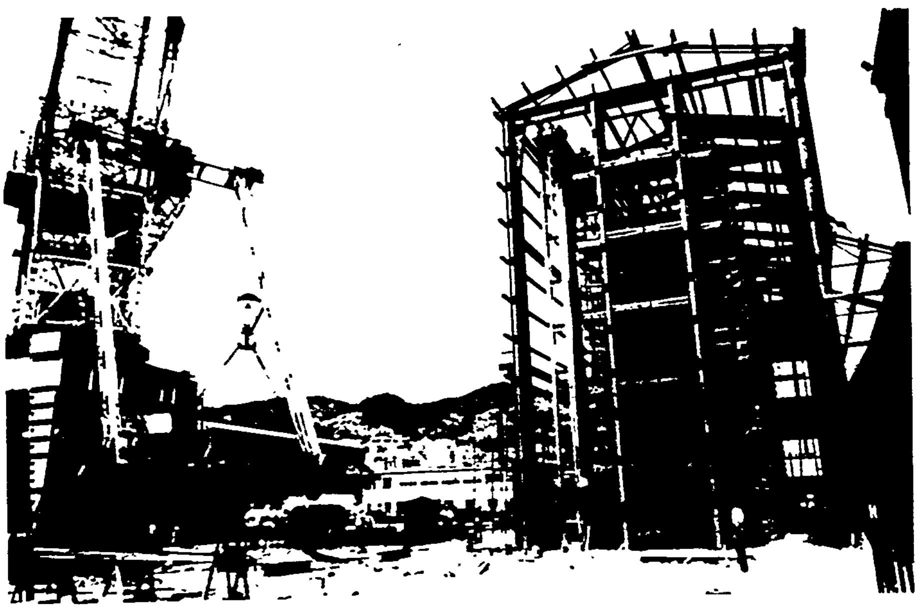


Figure 3

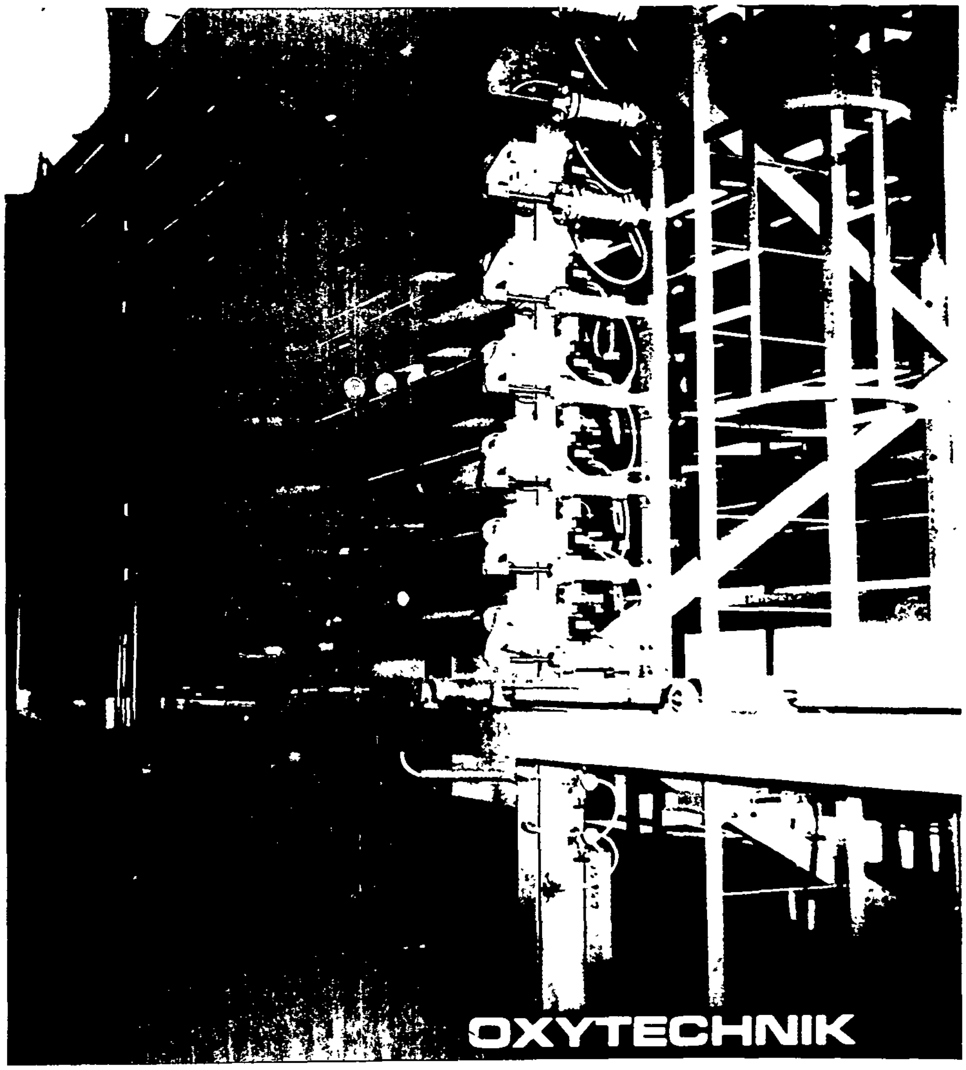


Figure 4

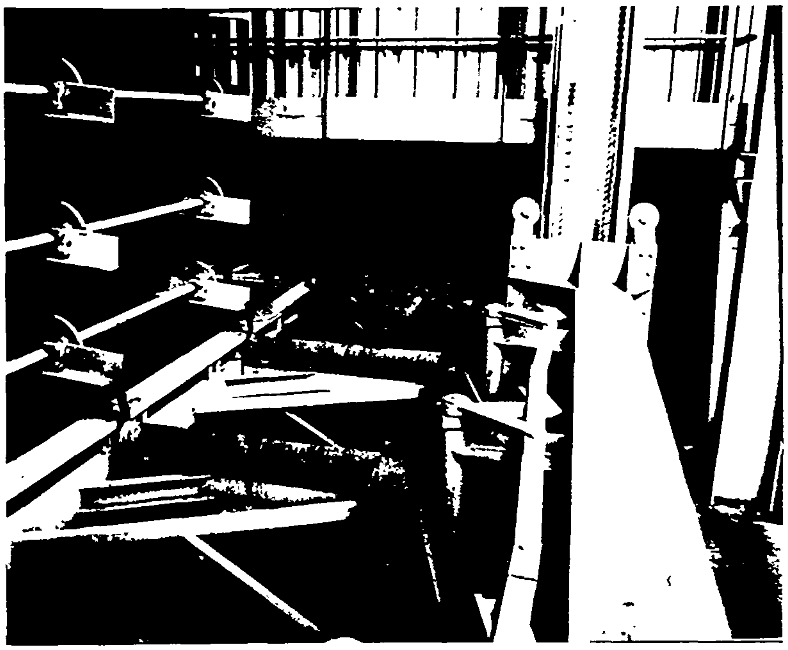


Figure 5

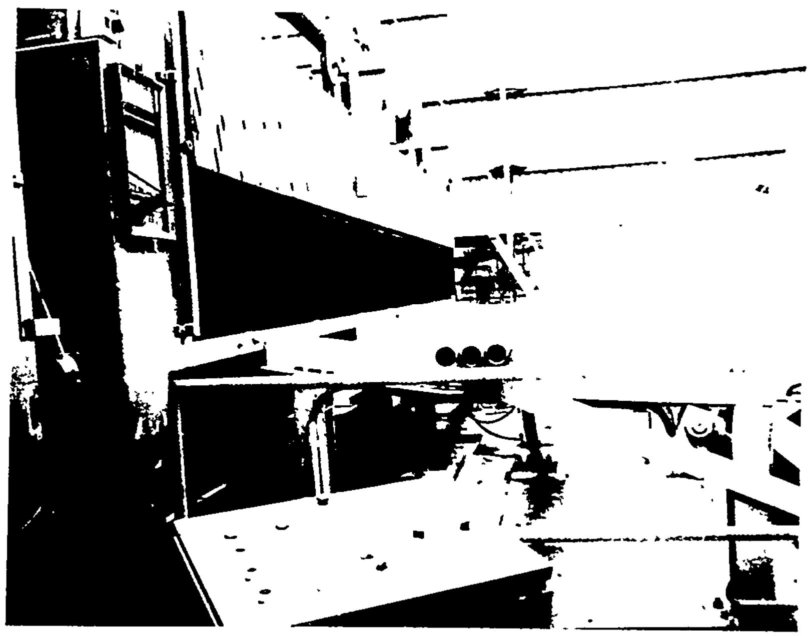


Figure 6

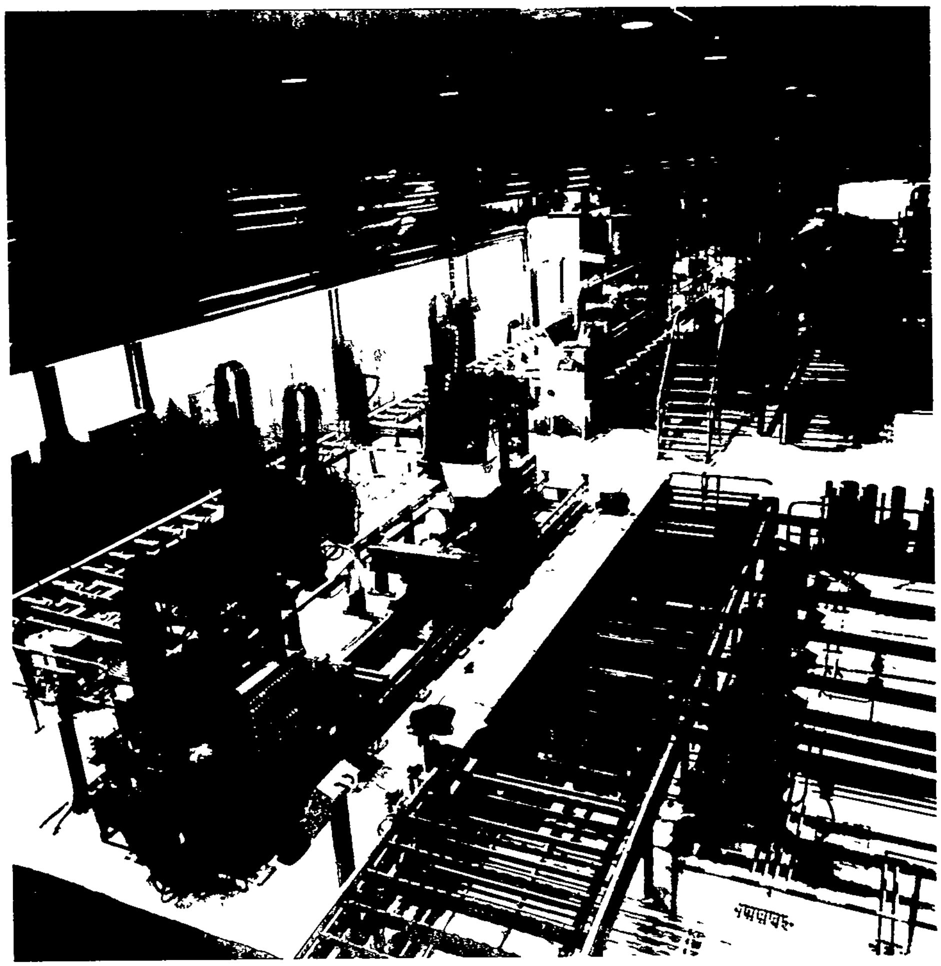
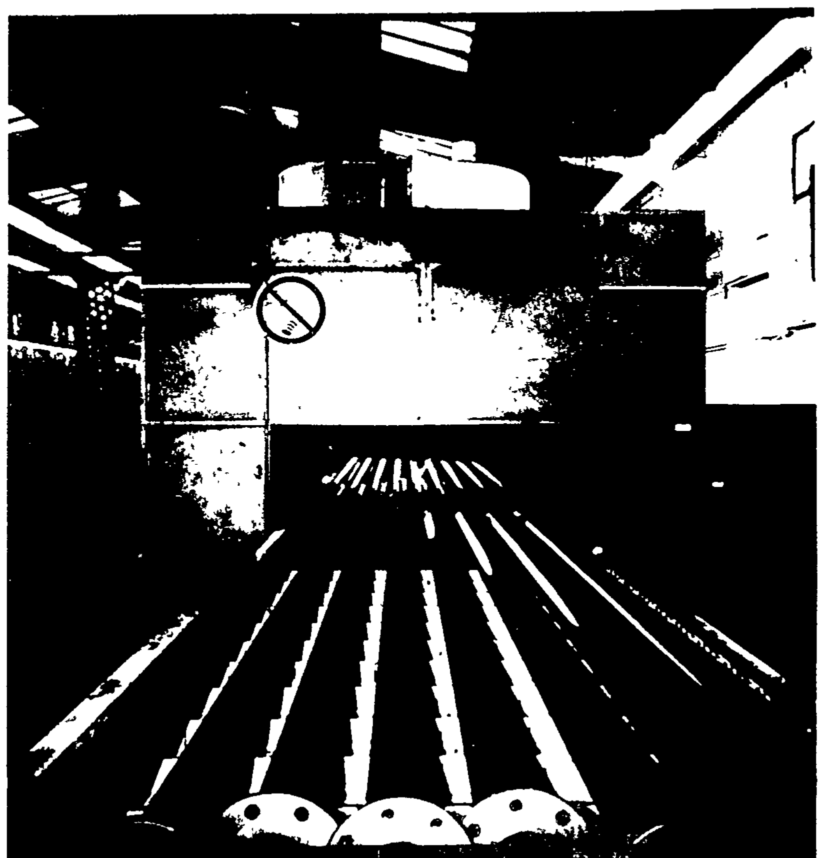


Figure 7



23.00.9

Farbgrundierung von Rohrteilen

OXYTECHNIK

Figure 8

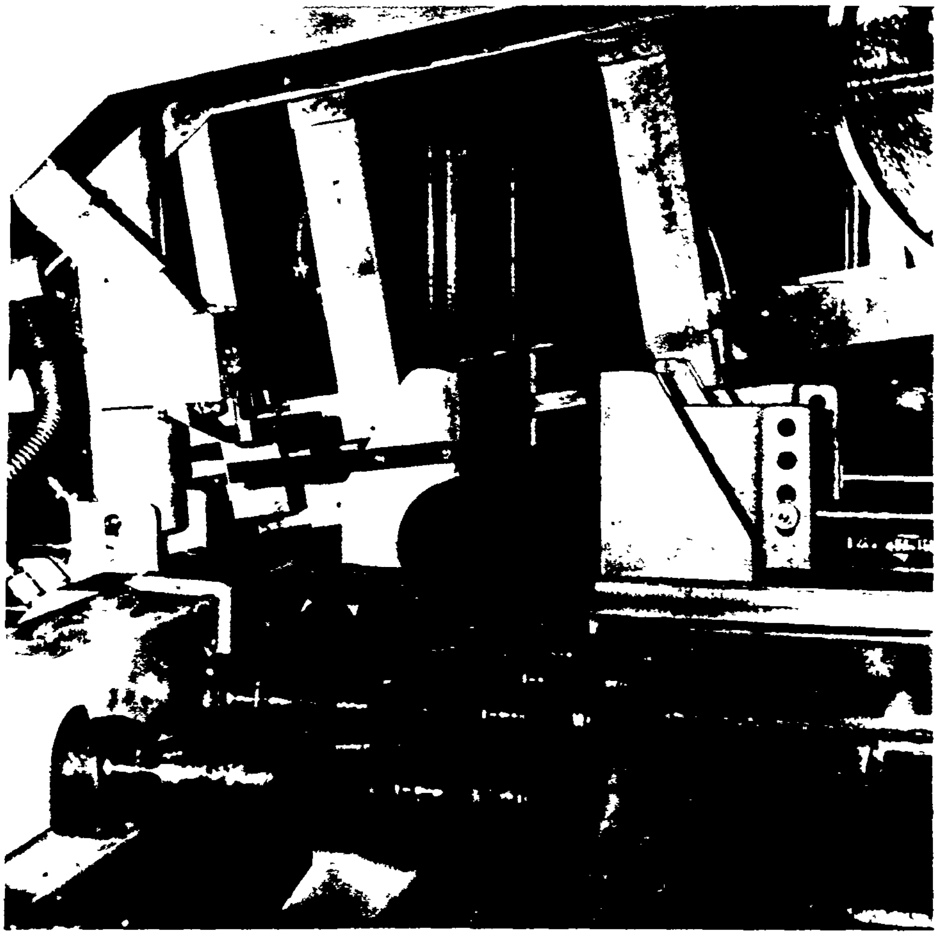


Figure 9

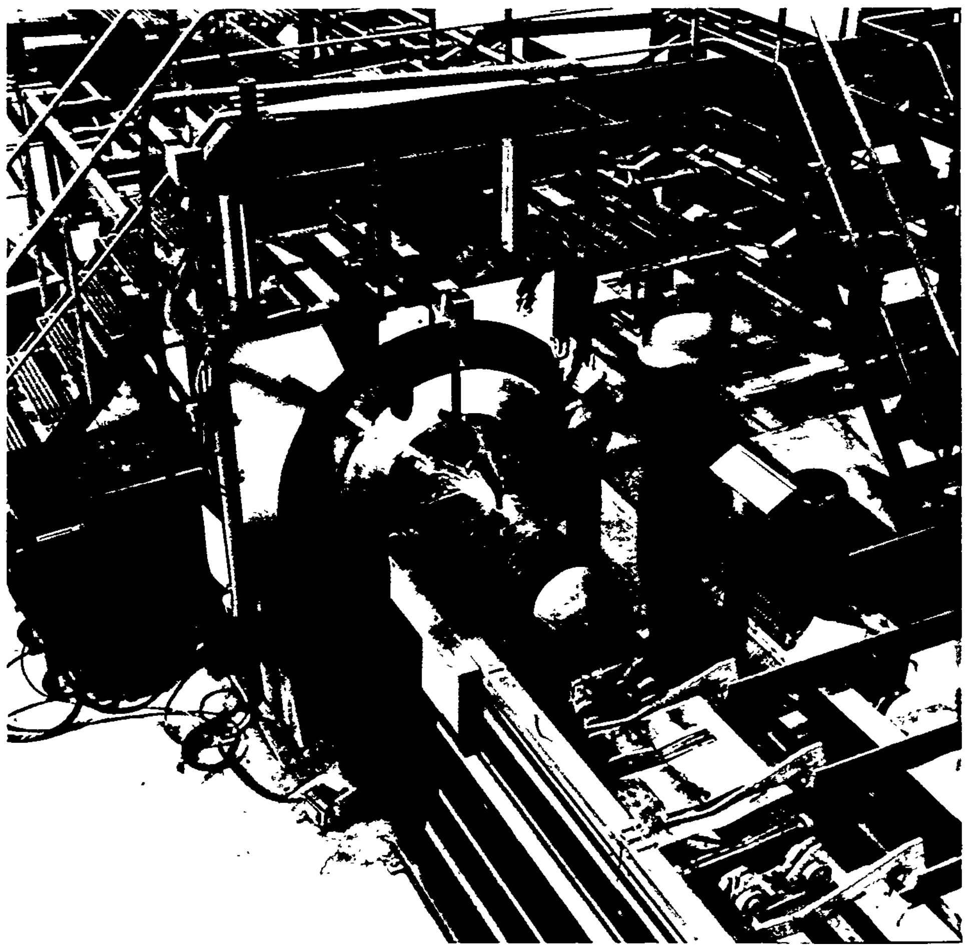


Figure 10

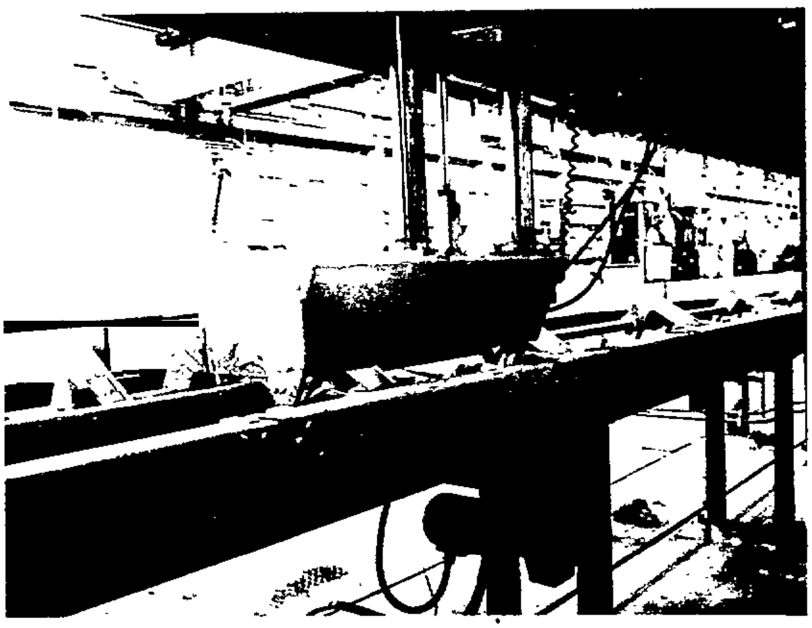


Figure 11

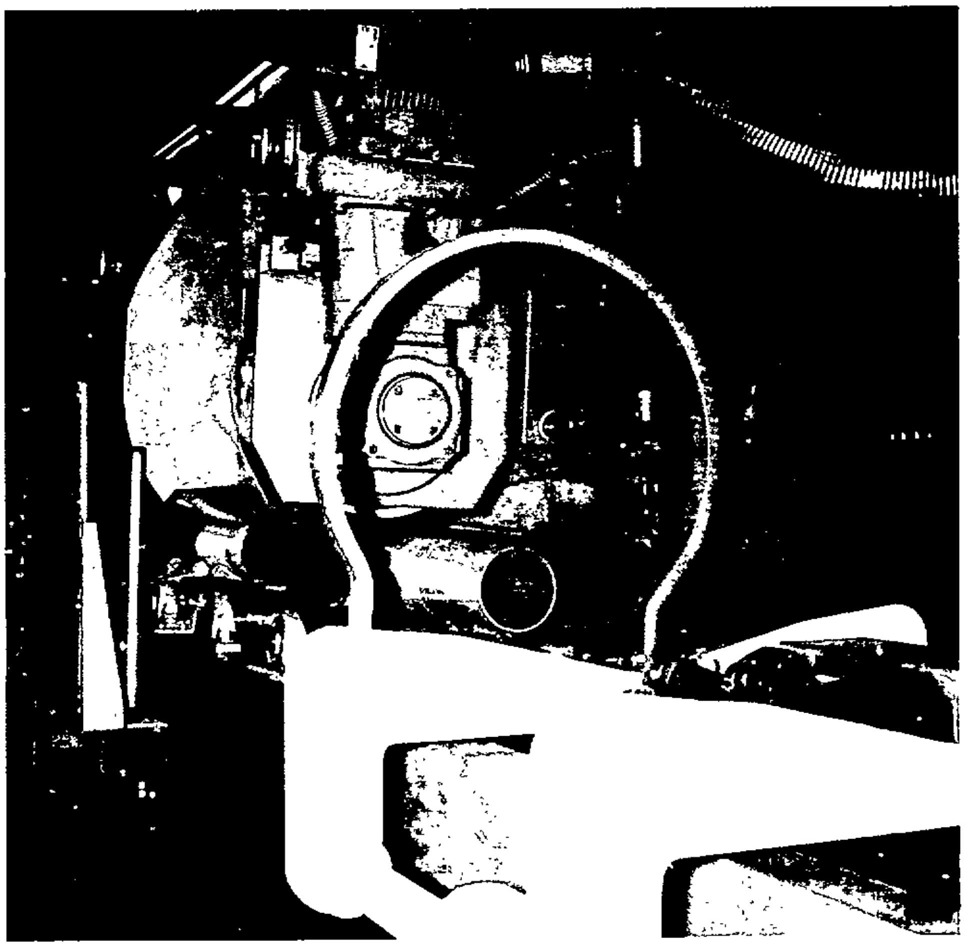


Figure 12

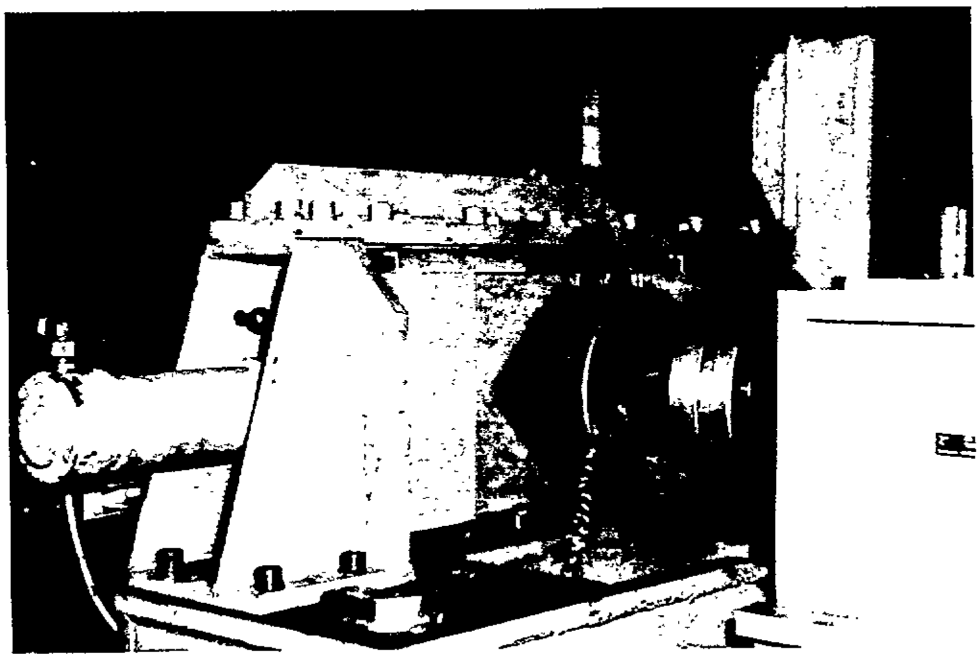


Figure 13

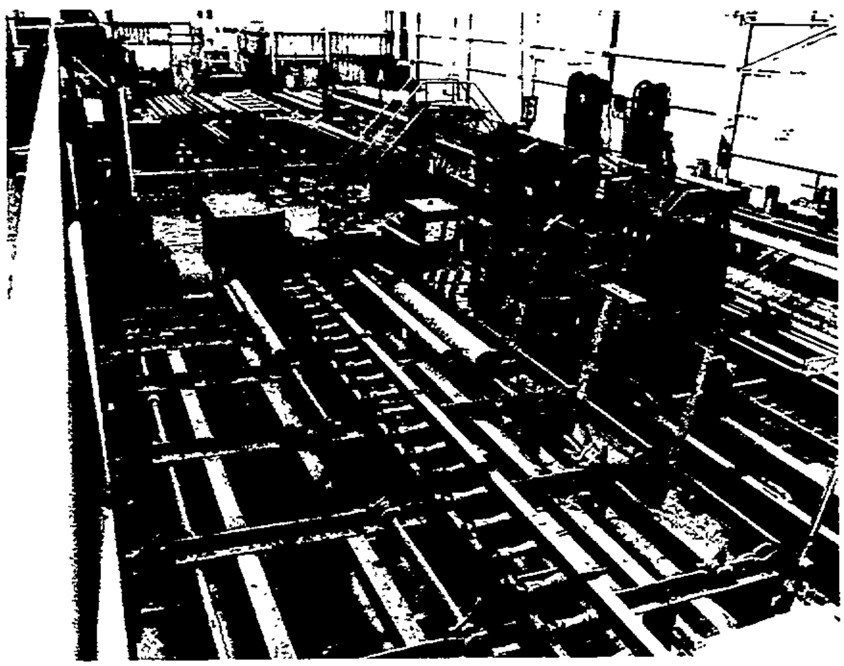


Figure 14

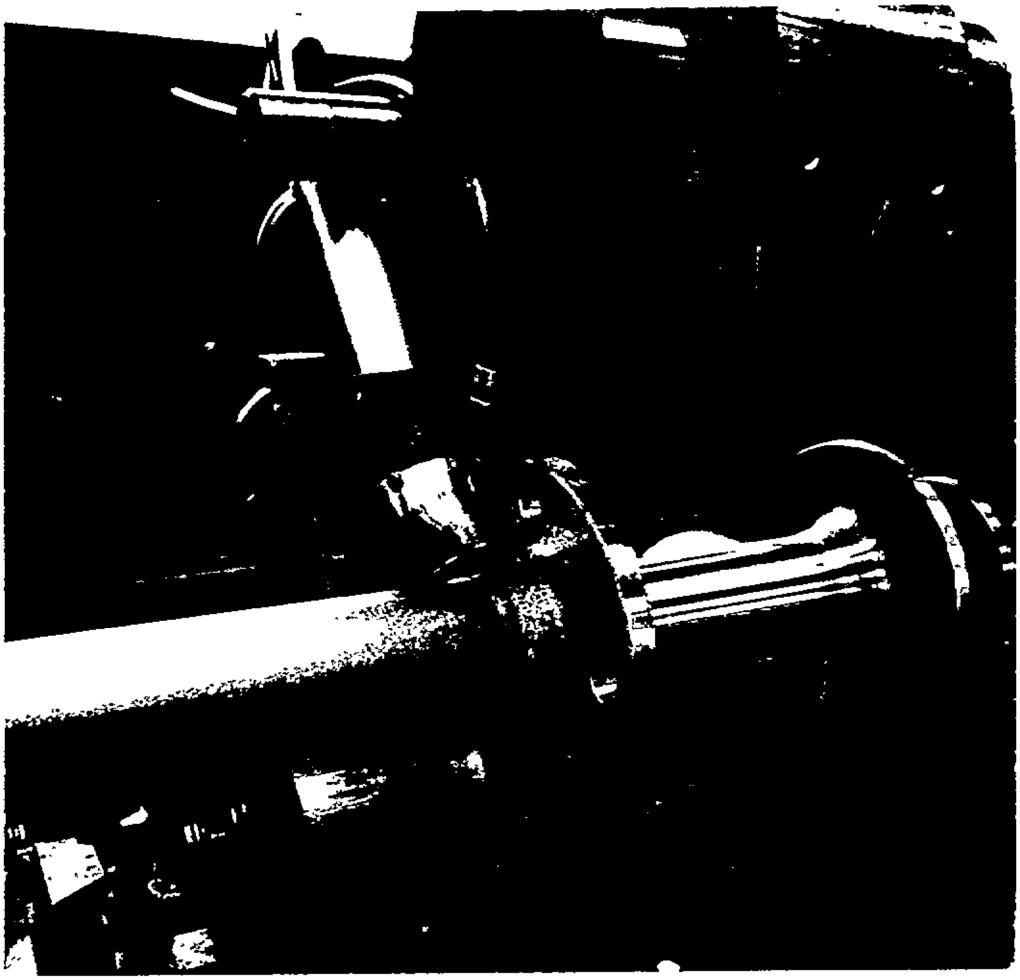


Figure 15

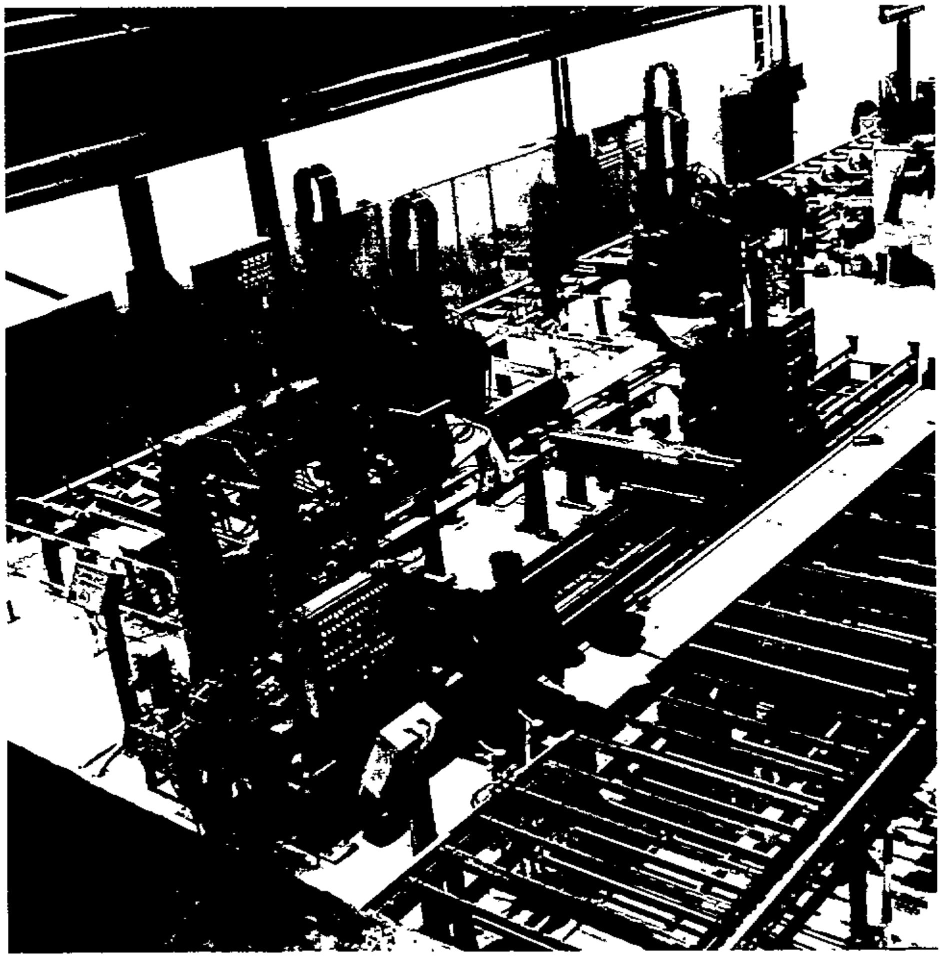


Figure 16

Figure 17

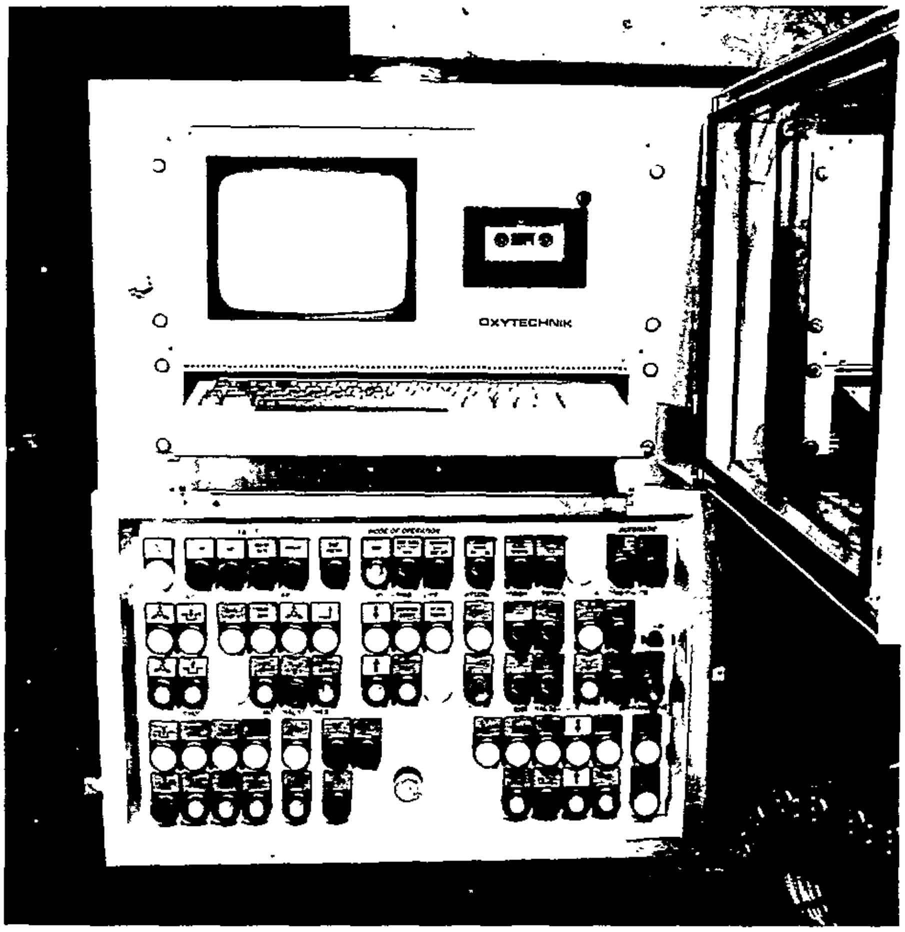


Figure 18

Figure 19

Figure

EVALUATION OF PIPE PROCESSING 'DATA

GENERAL DATA INPUT

-PIPE DIAMETER AND MATERIAL
-BENDING RADIUS
-ELONGATION FACTOR
-LENGTH OF SCRAP CUT
-MINIMUM FEED-IN LENGTH
-BORE HOLE QTY, AND FLANGE DIMENSION
-CUTTING WIDRH

INDIVIDUAL DATA INPUT

-PIPE IDENTIFICATION NUMBER
-QUANTITY OF FLANGES PER SPOOL
-ALL COORDINATES X,Y AND Z DESCRIBING THE SHAPE OF THE SPOOL
-QUANTITY OF EQUAL SPOOLS

DATA OUTPUT

-PIPE SILO
MINIMIZING OF PIPE REMNANTS RESPECTIVELY OPTIMUM DISTRIBUTION OF THE CUT LENGTH TO THE DELIVERY LENGTH
-LENGTH MEASURING AND SAWING EQUIPMENT
CUTTING LENGTH UNDER CONSIDERATION OF QUANTITY OF BENDS IN ONE SPOOL
-PIPE FLANGE WELDING MACHINE
BOLT HOLE ANGLE OFFSET, IF REQUIRED
-COLD BENDING MACHINE
FEED-IN LENGTH AND LINEAR DISPLACEMENT BETWEEN TWO BENDS, BENDING ANGLES; ROTATING ANGLE BETWEEN TWO BENDS

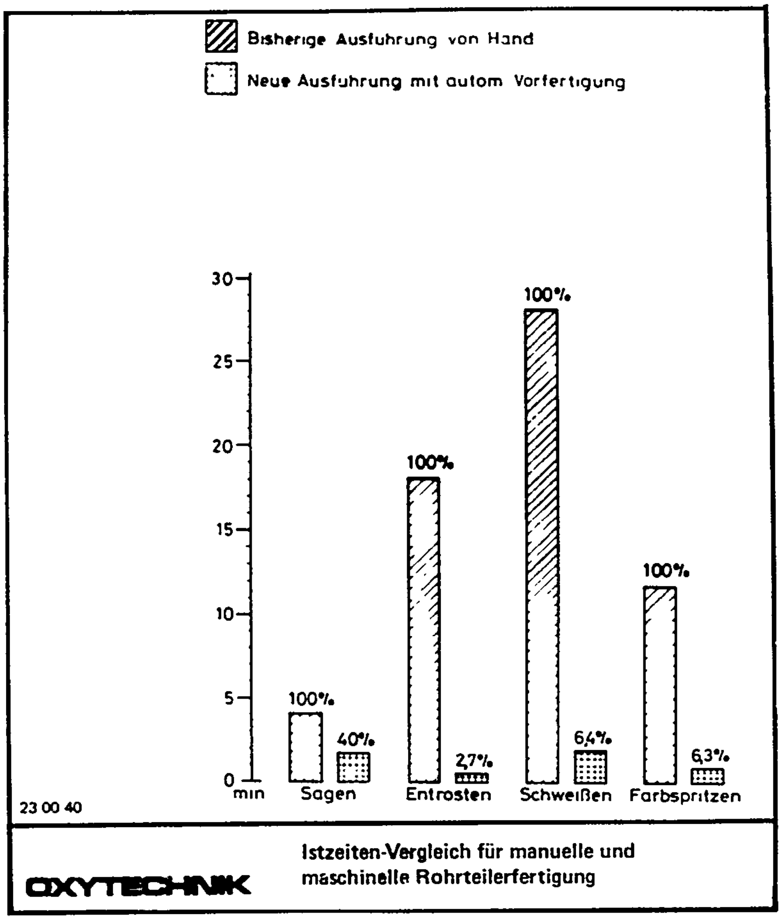
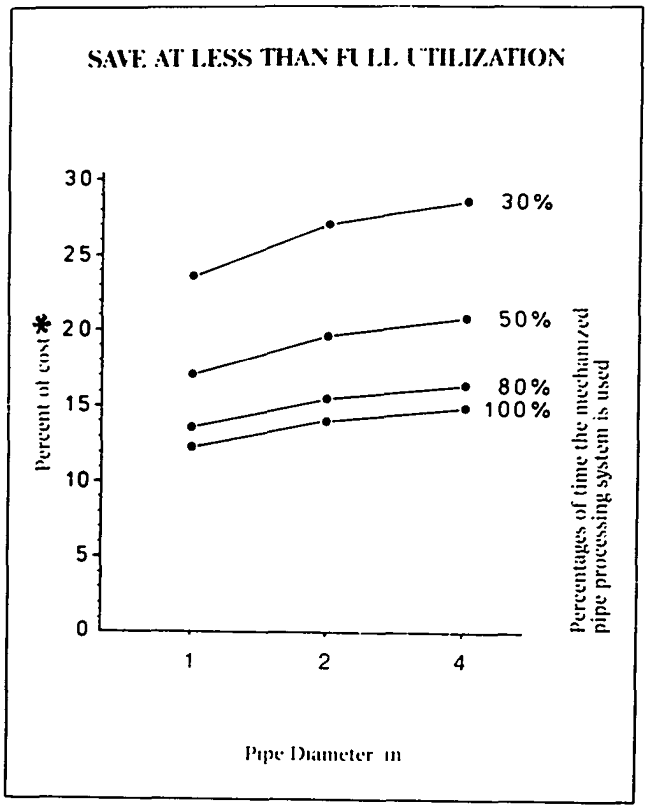
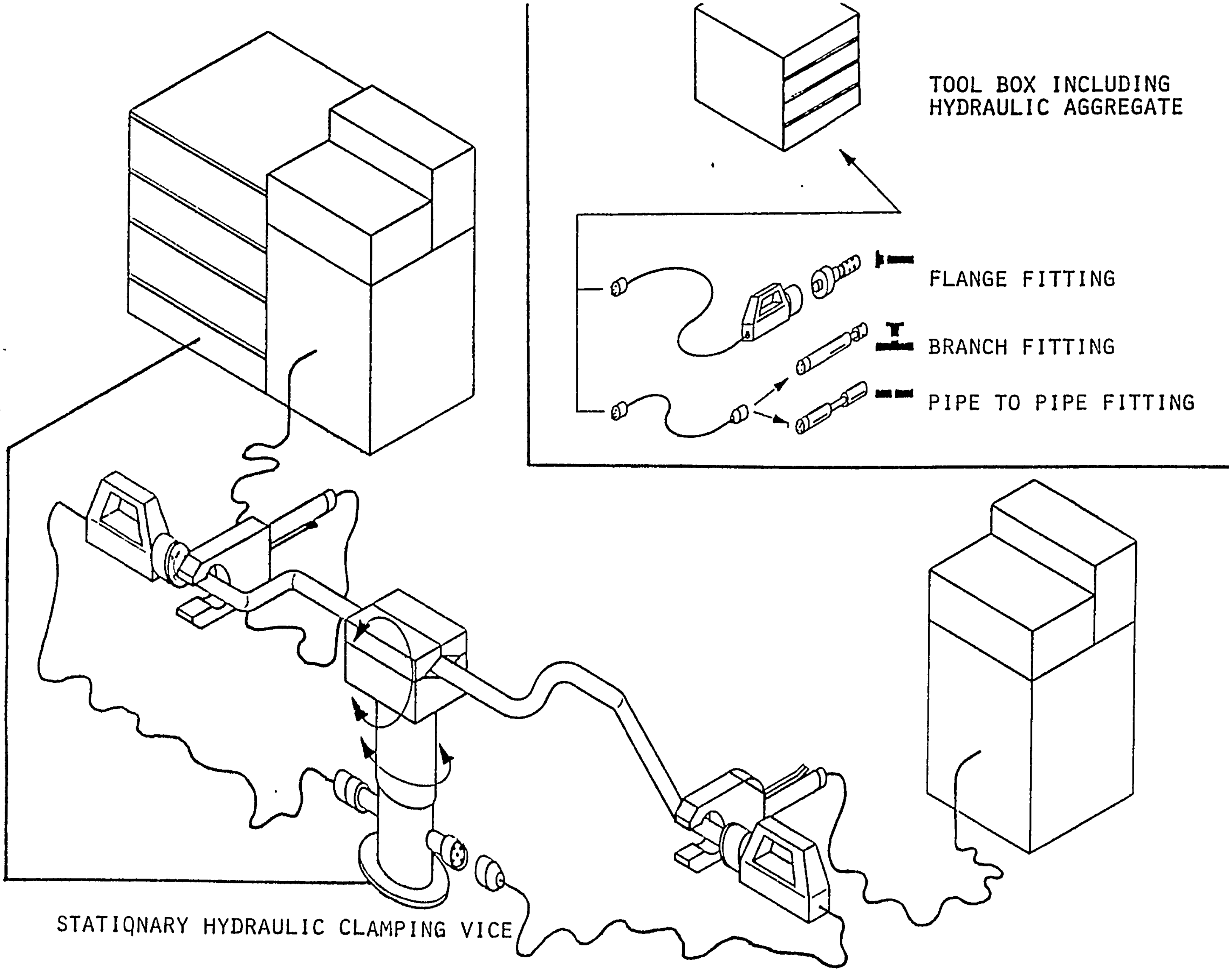

Bisherige Ausfuhrung von Hand
Neue Ausfuhrung mit autom Vorfertigung
30
25
20
15
10
5
0
min
100%
40%
2,7%
6,4%
6,3%
Sagen
Entrosten
Schweißen
Farbspritzen
23 00 40
OXYTECHNIK
Istzeiten-Vergleich für manuelle und maschinelle Rohrteilerfertigung

Figure 21



*100 = *Production cost for manual fabrication. At 100 percent utilization the system produces 4-inch i. d. pipes at 14 percent of the cost of manual production. At 30 percent, cost is 27 percent manual.*

Figure 22



PIPE CLAMPING SYSTEM, NB 1" - NB 8"

Figure 23

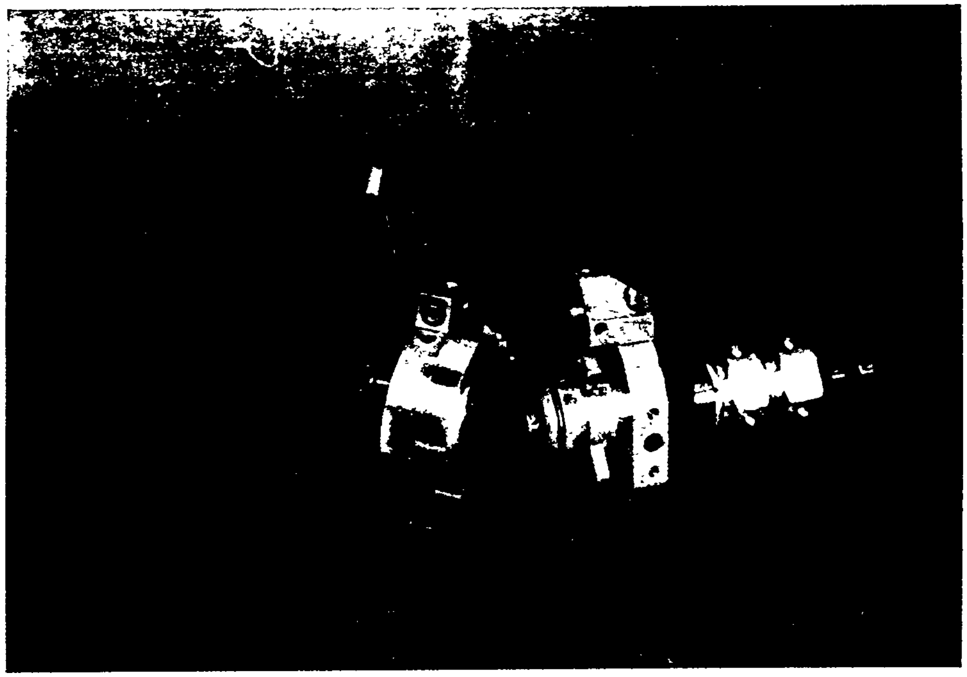


Figure 24

Figure 25

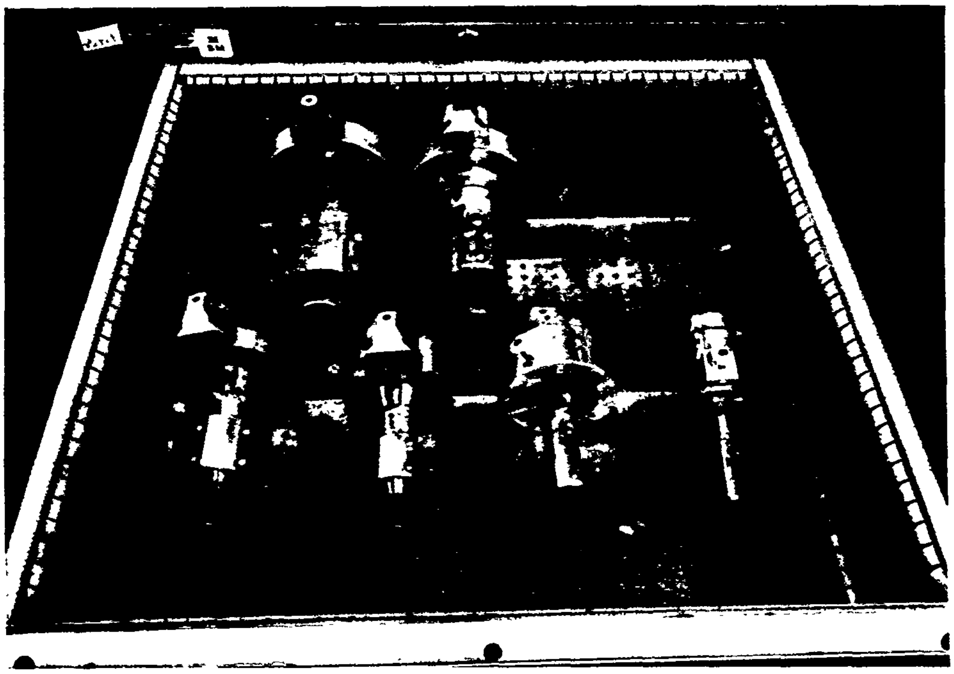


Figure 26

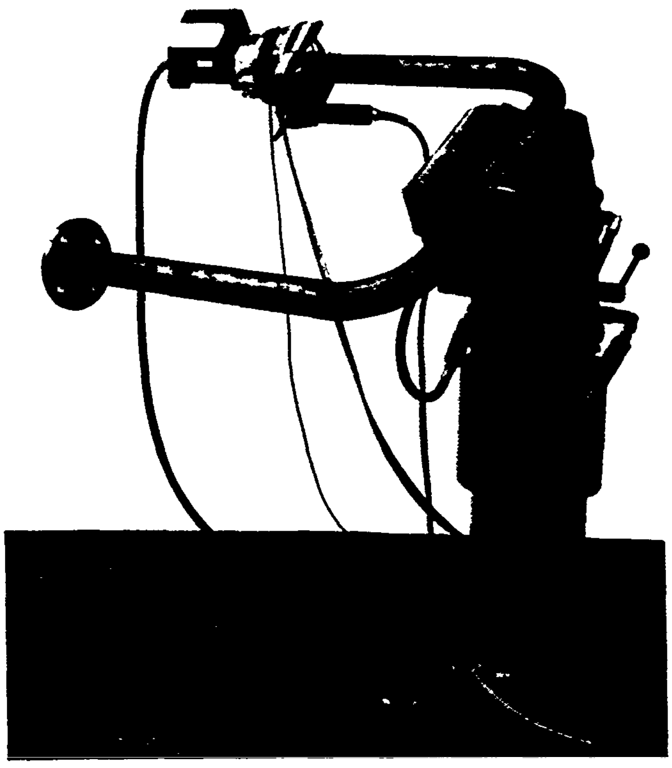
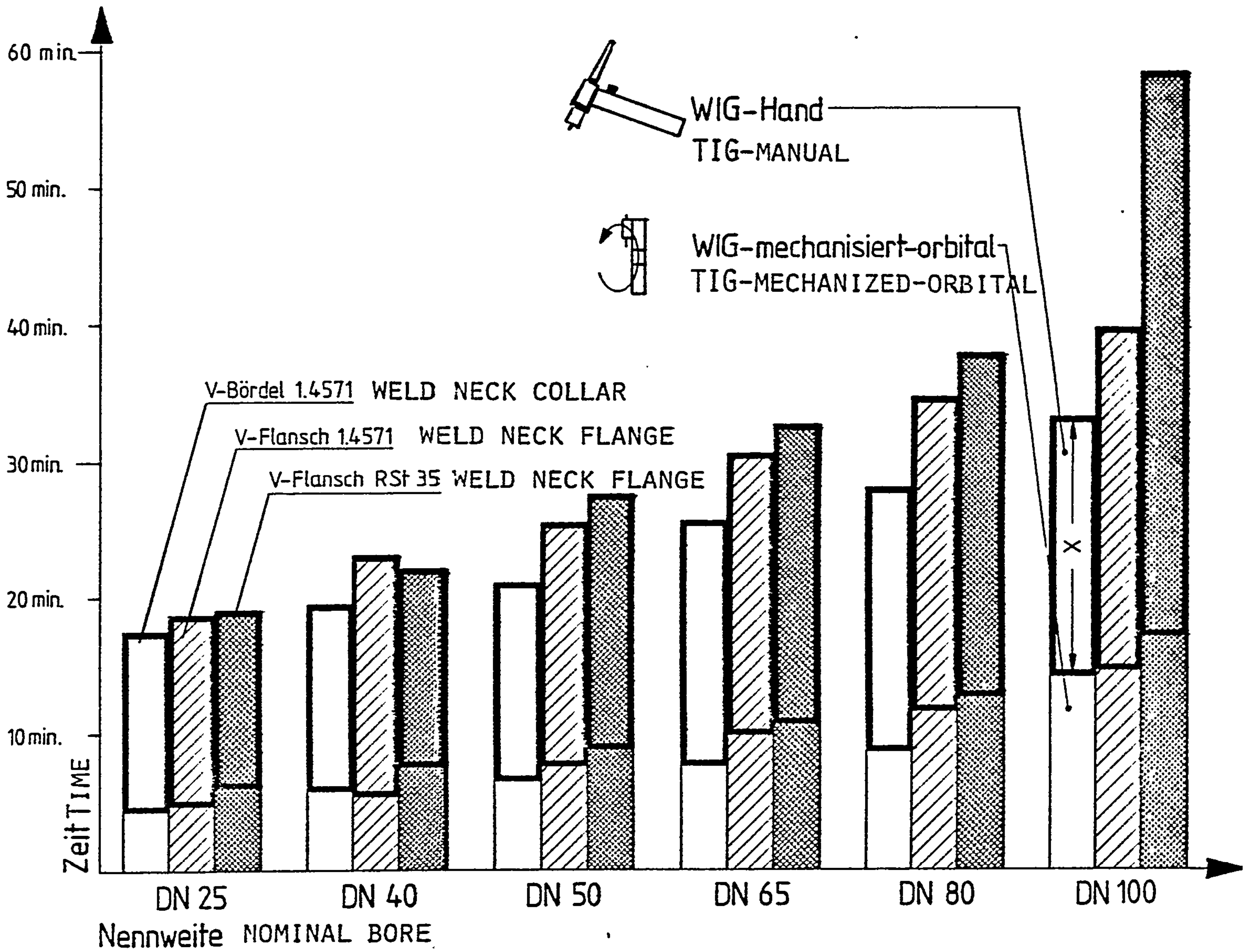


Figure 27



X=Einsparung (Gesamteinsparung = 68,7 %)
X=SAVING (TOTAL = 68,7 %)

XYTECHNIK hborn	Vorgabezeitvergleich TIME COMPARISON (CUTTING, CLAMPING AND WELDING)	Figure 28

Figure 29

CAD/CAM IN A NAVAL REPAIR YARD-UPDATE

J. Renard
Head, Computer Applications Branch
Long Beach Naval Shipyard
Long Beach, California

Mr. Renard as Head of the Computer Applications Branch at the Long Beach Naval Shipyard is currently responsible for the development, operations, and performance analysis of the Shipyards Computer Aided Design and Computer Aided Manufacturing System. He is involved in every aspect of design and manufacturing interfaced with the integrated and distributed system servicing all shipyard departments. He formerly was manager of Systems Engineering for Bechtel Corporation.

Mr. Renard is a graduate of the City University of New York with a Bachelor of Science Degree in Mechanical Engineering and graduate work, MS Electrical Engineering and MS Mathematics at UCLA. He is licensed as a professional engineer in Arizona, California, and New York.

Frank Nigro
CAM/NC Machine Tool Coordinator
Long Beach Naval Shipyard
Long Beach, California

Mr. Nigro is currently coordinator for the mechanical group, production department. He also serves as the supervisor of N/C CAM manufacturing planners, and supervisor of operations for the unigraphics CAD/CAM system which is located in the manufacturing CAD/CAM facility. He has worked for the Federal Government in naval shipyards for over 40 years in the field of manufacturing having served as an apprentice machinist at the New York Naval Shipyard and as a journeyman machinist, apprentice instructor, and production N/C programming foreman. Mr. Nigro has been directly involved with CAM Manufacturing processes and N/C technology since 1963. He has served as supervisor of numerical control manufacturing planning since 1968 and was instrumental, along with Mr. Jack Renard, in forming the Long Beach Naval Shipyard joint CAD/CAM program and N/C Steering Committee in 1969/1970. He has served as the committee cochairman for 12 years while working to develop and implement long-range goals for CAD/CAM with a view toward an eventual navywide totally distributive CAD/CAM system for all naval shipyards.

ABSTRACT

A recordation of achievement and growth of an integrated program in the field of CAD/CAM technology is represented. Dealing with the Long Beach Naval Shipyard (LBNS) Joint Planning/Production Computer Applications Program for Computer Aided Deisgn (CAD) and Computer Aided Manufacturing (CAM) activities, analyses and operational results related within recent calendar years are covered. The CAD effort on behalf of the Planning Department and the CAM operations on behalf of the Production Department are part of the overall Naval

Ship Design/Construction Program formulated to bring unification into the total manufacturing sequence beginning with the design stages and going through the parts-production phases performed by processed planning (numerically controlled (N/C) machine tools. Complete unification among the diverse elements of design, drafting analysis, and machining was achieved at LBNS during 1980 with the introduction of the total, integrated, interactive computer/software system. The joint computer applications program has been highly cost effective, having net returns, based upon cost, of well above 15 to 1.

Actual production is affected by a combination of schedule jobs, skilled N/C machinists, maintenance for machine tools/control centers, excessive machine tool downtime, lack of qualified maintenance personnel, and transfer of jobs from N/C tools to manual machines or inappropriate N/C tools. The integrated, computer-aided design, drafting, and manufacturing system communications between planning and production permitted rapid, concurrrent solutions to design/production problems across the interface. The enhancement of the computer system in the CAD/CAM operations led to improved schedules, reduced job cost, smoother and swifter communications, diminished lead times, and drawing/model changes as compared with the prior system. With this unique system, LBNS leads all other shipyards in CAD/CAM.

INTRODUCTION:

1. The Long Beach Naval Shipyard (LBNS) is one of a complex of eight shipyards tasked with the repair, overhaul, and modernization of ships of the U. S. Navy. The shipyard initiated a computer application program during 1972 and in the intervening period to the present time the program has been upgraded by utilization of large main frame computers, peripherials, remote terminals, analytical program libraries, and computer graphics hardware and software all applied to increasing productivity of the shipyard and increasing reliability of ships systems. The CAD/CAM 'effort in behalf of the Planning and Production Departments is formulated to bring unification into the total manufacturing sequence beginning with the design stages and going through the parts-production phases performed by Numerically Controlled (N/C) machine tools and other fabrication methods. Complete unification among the diverse elements of design, drafting, analysis, machining, and fabrication was achieved during 1980 with the introduction of interactive computer/software to achieve a totally integrated computer aided manufacture system.

2. Computer Aided Design and Manufacturing (CAD/CAM) refers to the use of automation to carry out all or part of the manufacturing sequence beginning with design and following through to the finished product. A variety of Numerically Controlled (U/C) tools are used to automatically produce a wide variety of parts. N/C tools can be operated in the manual mode by an operator, but more often function automatically with special tapes mounted on the tool controller reader/microprocessor. Preparation of the tape and accompanying instructions are the keys to the process.

Recent developments in the computer industry, particularly in graphics, have simplified and speeded up the preparation process for design and preparation of control tapes and have made advanced concepts such as direct numerical control (DNC) of S/C tools controlling the tool operation directly from the computer without use of control tapes possible. The integrated, design, drafting and manufacture system led to substantially enhanced operations., with complete interconnecting communications between Planning and Production Departments permitting rapid, concurrent solution to design/pro-

2. Continued

duction problems across the interface between the two groups. The application of C4D/CAM operations led to improved schedules, reduced job cost, smooth and swifter communications, diminished lead time, and fewer drawing changes compared to conventional operations.

2.0 INTERACTION - ENGINEERING/MANUFACTURING

1. The elements necessary in the present day manufacturing environment are complex and designers and shop parts programmers interact with a wide range of different functions. For example, a machinist can perform milling operations on high quality stock and by utilizing welding techniques build layered part similar to a casting but with far superior characteristics. In another example, interaction with design ensured the correct interpretation of necessary geometries in designing propellor gages. Computer Aided techniques were developed and programmed to assure smooth continuous curvatures. The IBM Automatic Programmed Tool (APT) Intermediate and Advanced Contouring system is used to obtain the tangencies between generated tabulated cylinders and blend-in radii for the cylindrical, fillet normal, and edge gages. The on-line plotters are used to check conformity with design requirements as well as to obtain accurate scale drawings. For the sheetmetal shop, a system of special programs have been created for automating the development and layout of sheet metal ducting systems. Ducting elements can be displayed in both 3-D isometric and Flat pattern forms. The collection of these programs provides a capability for automating practically any ducting requirement. An extension of this capability is in the use of numerically controlled burning equipment, in structural lofting, and nesting.

3.0 LONG BEACH NAVAL SHIPYARD (LBNS) OPERATIONS

1. The LBNSY operation includes both CAM and CAD. The effort of overall design accomplished before or in parallel with the shop preparation for manufacturing, also employs computers and is known as Computer Aided Design (CAD). Computer Aided Design is broad in scope. It not only includes production of design drawings, but for many years has included various types of technical analyses contributing to acceptable and reliable

part and/or structural equipment designs as well as providing other necessary technical data. Intercommunications take place via computer terminals located in the Design Division and the terminals located in the shops - in real time. Employing a common data base, design and the shops have proceeded in concert to manufacture and to produce many parts manufactured with N/C machine tools; also detail, layout and arrangement drawings are produced interactively via the distributed computer terminals. Design and the shops use the UNIGRAPHICS graphics computer system and, as the need arises, large scale utility computer systems for design analysis, and preparation of the detail shop drawings. The LBNSY has utilized CAM and CAD for some 10 years now. Millions of dollars in cost savings have accrued and productivity has been quite materially enhanced. The system configuration is unique in the access by the shipyard to a complex of HOST computers provided by special control software which provides remote terminal capability to the minicomputer and to a remote job entry terminal in Design. In total capability, the Design Division is provided with a two (2) and three (3) dimensional drafting/design interactive graphics system together with the provision for designers to access HOST computer analytical libraries for the performance of variety of engineering analysis. The production shops are provided with capability for full 5 axis machining, automated sheetmetal ducting fabrication, lofting and welding system.

2. The resource availability to the Long Beach Naval Shipyard system is illustrated in Figure 1; these system elements are the result of the introduction of graphics, and the orderly studied growth of the system to a full CAD/CAM system. In order not to diminish any of the capabilities of the system existing prior to the introduction of interactive graphics full batch operations and remote access to HOST computers were maintained. The services provided the shipyard include access to a complex of main frame HOST computers; IBM 370/3033 and CYBERS CDC 176 including the UNIGRAPHICS software installed in the PDP 11/70 minicomputer. The latter equipment is capable of operating in stand-alone mode or as a remote job entry terminal as the means for HOST computers access. The system now installed performs all functions of Computer Aided Design and Computer Aided Manufacturing thus integrating the total manufacturing process.

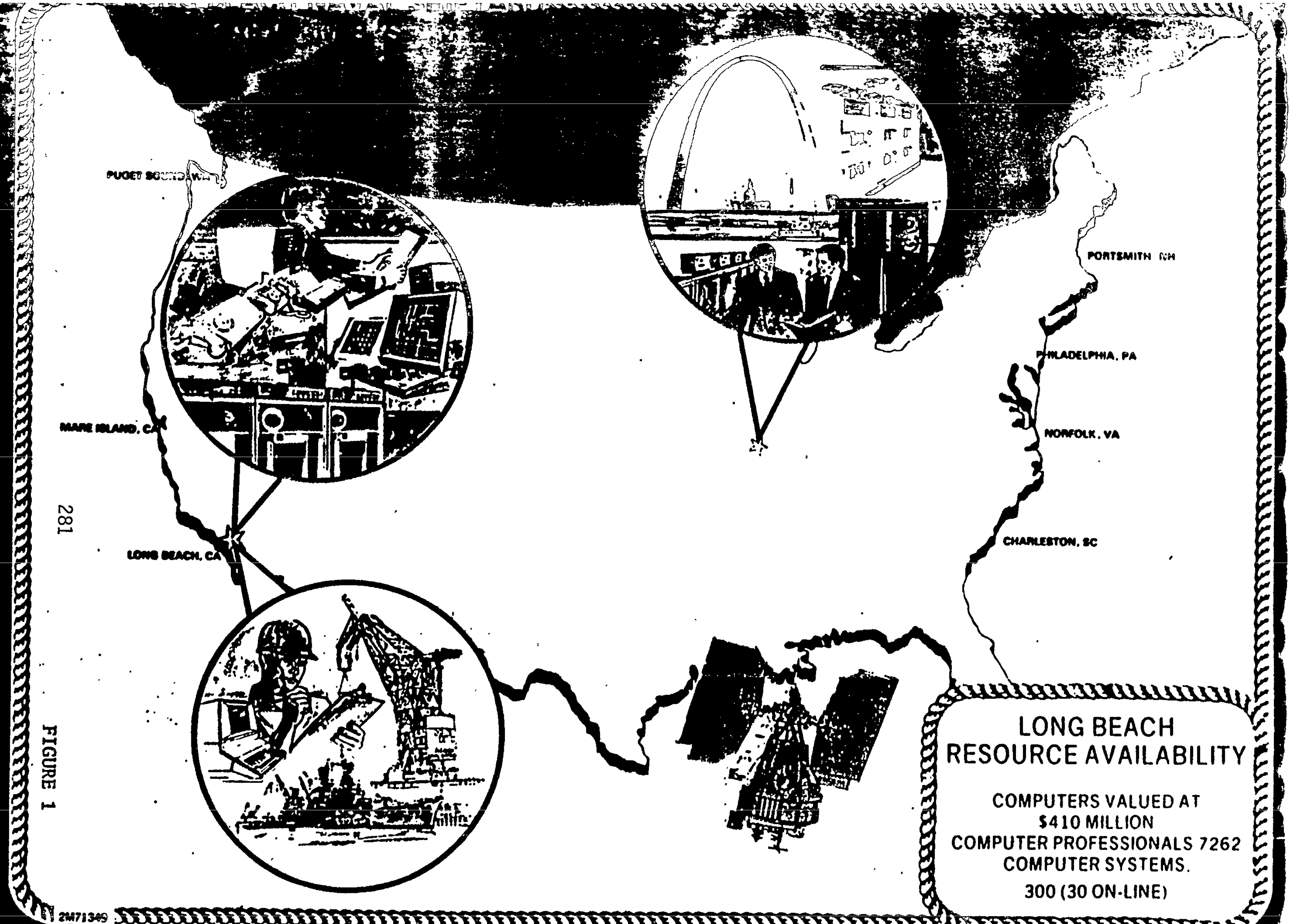

PUGET SOUND, WA
MARE ISLAND, CA
LONG BEACH, CA
PORTSMITH NH
PHILADELPHIA, PA
NORFOLK, VA
CHARLESTON, SC
LONG BEACH
RESOURCE AVAILABILITY
COMPUTERS VALUED AT
$410 MILLION
COMPUTER PROFESSIONALS 7262
COMPUTER SYSTEMS.
300 (30 ON-LINE)
2M71349

FIGURE 1

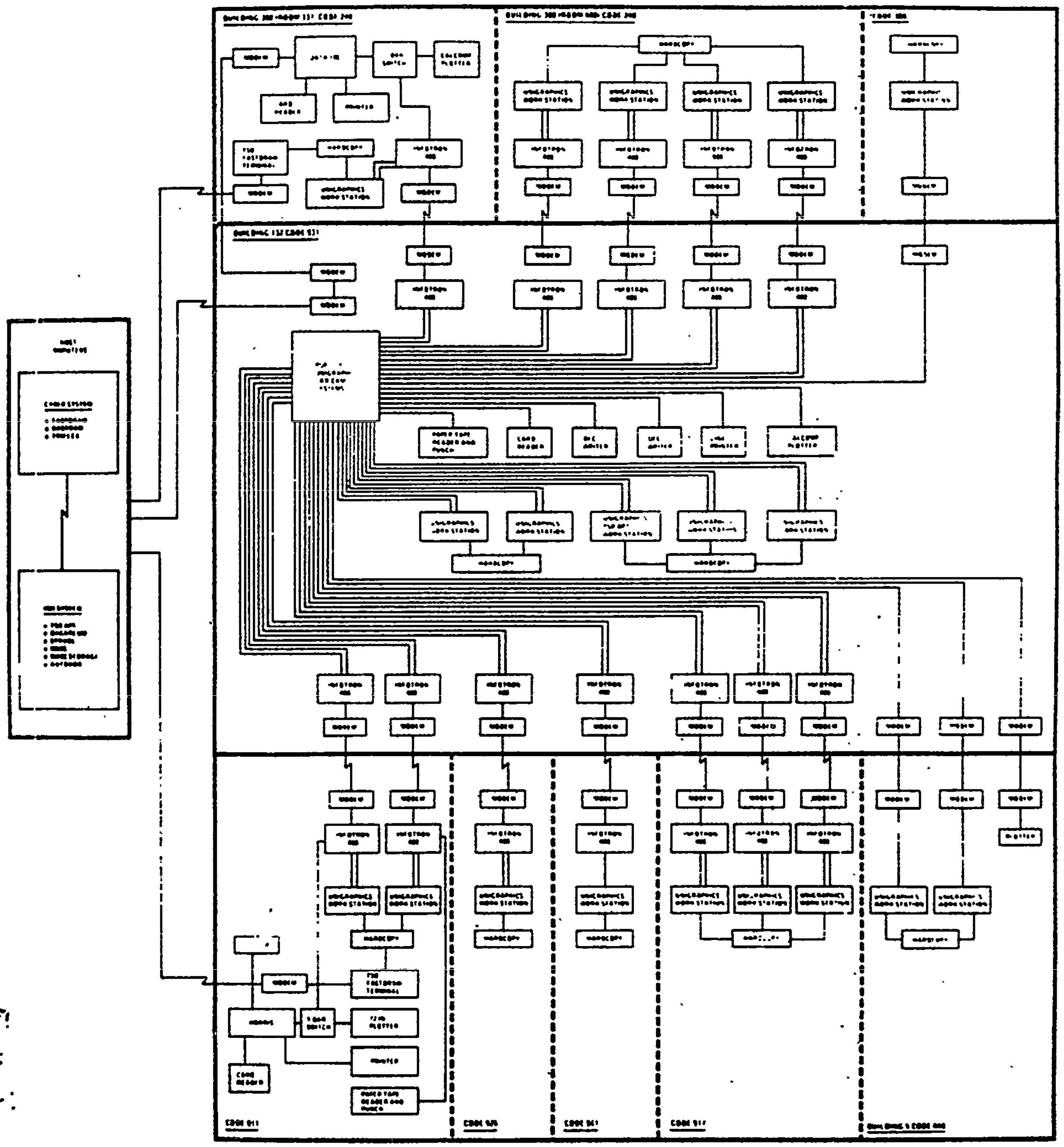
4.0 CURRENT SYSTEM

Figure (2) illustrates the configuration of the shipyard wide integrated CAD/CAM system, and in particular the graphics and remote terminal hardware installed in the Design Division and Production Department. All equipment is leased under a computer services contract and configured to shipyard specifications. As noted, work stations are installed in the Design Division, the Mechanical Group, and the Structural Group. Thou this configuration, a design/production data base containing engineering design and manufacturing data has been established. The information on file at the DEC ADP 11/70 is rapidly accessible to all users by random access via the employment of fast disc storage. All work stations are interconnected via 9600 BAUD communications to the minicomputer centrally located within the shipyard and to the HOST computers external to the shipyard. As drawings and manufacturing data are completed, the file created is stored on magnetic tape and can be retrieved/modified on demand of the user with the appropriate system clearance.

Supplementing the configuration previously shown is the list of equipment located within the Planning/Production areas figures (3) thru (9). Note that both batch and interactive operations are available to the designers and production peraonnel. The systems are interconnected to the HOST computers for large scale analysis and to the minicomputers for drafting, design and solution to engineering problems of analysis and design. The PDP 11/70 system with the RSX-1lM operating system provides other functions such as a FORTRAN compiler, text editing, and the data base for many applications; e.g., accountability system, document storage, pattern and drawing storage.

Illustrated is the typical UNIGRAPHICS work station Figure lO; a keyboard selector provides the user access to the UNIGRAPHICS system's software unique functions required to perform the job; e.g., image control, layer control, automatic dimensions, creation of model, etc. The message monitor provides the function of a tutorial and assists the users in the generation of his design drawing or manufacturing display as well as performance of the required analysis. The hairline cursor is set for the purposes of correction, deletions, etc. of the display. Two types of CRT's are employed, the

LONG BEACH NAVAL SHIPYARD



CAD/CAM SYSTEM

LBNS

FIGURE 2

PLANNING DEPARTMENT
CAD/CAM SYSTEM
DESIGN DIVISION

REMOTE COMPUTER TERMINAL CONFIGURATION

DATA 100 SYSTEM 78-111
TERMINAL CONTROL UNIT
LINE PRINTER ADAPTER
300-TO-600 LPM PRINTER
CARD READER ADAPTER
CARD READER, 150-TO-300 CPM
CRT OPERATOR CONSOLE AND ADAPTER
IBM CONSOLE RMT/306 FEATURE
PLOTTER ADAPTER
CALCOMP INSTRUMENTS PLOTTER - 36 INCH
CALCOMP PLOTTER SOFTWARE

LBNS

FIGURE 3

PLANNING DEPARTMENT
CAD/CAM SYSTEM
DESIGN DIVISION
REMOTE COMPUTER TERMINAL CONFIGURATION
(CONTINUED)

IPF SOFTWARE FOR PLOTTING, IBM 370/168/3033 COMPATIBLE

ONE IBM 029-A22 MACHINE WITH COLUMN LOCATOR

2400-BAUD MODEM FOR DATA 100 SYSTEM

DEDICATED COMMUNICATIONS

TEKTRONIX 4014 INTERACTIVE GRAPHICS TERMINAL FOR ANALYSIS (DAC II)

TEKTRONIX HARDCOPY UNIT (ALSO CONNECTED-TO UNIGRAPHICS)

1200-BAUD MODEM FOR GRAPHICS TERMINAL TIME-SHARING (DAC II)

FIGURE 4

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PLANNING DEPARTMENT

CAD/CAM SYSTEM
DESIGN DIVISION

INTERACTIVE GRAPHICS SYSTEM CONFIGURATION

EIGHT UNIGRAPHICS IGS DESIGN WORK STATIONS

THREE TEKTRONIX HARDCOPY UNIT

9600-BAUD MODEM DEDICATED COMMUNICATIONS

FIVE MULTIPLEXORS FOR WORK STATIONS AND PLOTTER

9600-BAUD MODEMS FOR WORK STATIONS

SPECIAL SOFTWARE FOR OPERATING DESIGN PLOTTER WITH UNIGRAPHICS AND HOST COMPUTERS

T-BAR SWITCH FOR OPERATING TWO PLOTTERS CONCURRENTLY ON UNIGRAPHICS

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FIGURE 5

PRODUCTION DEPARTMENT
CAD/CAM SYSTEM
MECHANICAL GROUP – SHOP 31

ONE DIGITAL EQUIPMENT CORP — PDP 11/70 PROCESSOR
ONE " " " PDP 11/780 "

ONE 768 KB ECC/MOS MEMORY

- HARDWARE MEMORY MANAGEMENT DEC WRITER

TWO DISK STORAGE SUBSYSTEMS 5 G/B

- NINE-TRACK 800/1600 BPI MAGNETIC TAPE STORAGE SUBSYSTEM WITH CONTROLLER AND DEDICATED CABINET
- FLOATING POINT PROCESSOR
- ASYNCHRONOUS 8-LINE MULTIPLEXER
- RSX 11-M-EVENT DRIVER MULTIPROGRAMMING OPERATION SYSTEM WITH INSTALLATION AND MAINTENANCE

ONE MYLAR-RATED PAPER TAPE READER, 200 CPS AND PUNCH 120 CPS INCLUDING CONTROLLER

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FIGURE 6

PRODUCTION DEPARTMENT
CAD/CAM SYSTEM
MECHANICAL GROUP – SHOP 31
(CONTINUED)

FIVE UNIGRAPHICS INTERACTIVE DESIGN STATIONS
- 19-INCH STORAGE/RASTER CRT TERMINAL
- REFRESH MESSAGE MONITOR
- FUNCTION SELECT KEYBOARD — LEFT AND RIGHT DESIGN STATION TABLES
- TWO CPU-TO-DESIGN-STATION CABLES

ONE CALCOMP 960 VERTICAL BED PLOTTER
- CALCOMP 906 CONTROLLER
- PLOTTER INTERFACE CABLE
- UNIGRAPHICS PLOTTER SOFTWARE

ONE RJE/HASP WORKSTATION EMULATOR MODULE

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LBNS

FIGURE 7

PRODUCTION DEPARTMENT
CAD/CAM SYSTEM
STRUCTURAL GROUP — SHOP 17

THREE UNIGRAPHICS INTERACTIVE DESIGN STATIONS

- 19-INCH STORAGE CRT TERMINALS
- REFRESH MESSAGE MONITOR
- FUNCTION SELECT KEYBOARD
- LEFT AND RIGHT DESIGN STATION TABLES

TWO COMPUTER-TO-DESIGN-STATION CABLES

TWO RS 232 CEIA INTERFACE

- FOUR INFOTRON 480 SUPERMUX
- DEDICATED 9600-BAUD COMMUNICATIONS

ONE UNIGRAPHICS HARDCOPY UNIT WITH MULTIPLEXER AND TWO SOFT INTERFACE CABLES

ONE IBM 029-A22 KEYPUNCH MACHINE WITH IBM 1570 COLUMN LOCATOR

LBNS

FIGURE 8

PRODUCTION DEPARTMENT
CAD/CAM SYSTEM

STRUCTURAL GROUP — SHOPS ~~11~~, 26, AND 41

FOUR UNIGRAPHICS INTERACTIVE DESIGN STATIONS

- 19-INCH REFRESH COLOR CTR TERMINALS
- REFRESH MESSAGE MONITOR
- FUNCTION SELECT KEYBOARD
- LEFT AND RIGHT DESIGN STATION TABLES

THREE COMPUTER-TO-DESIGN-STATION CABLES

THREE RS 232 CEIA INTERFACE

- SIX INFOTRON 480 SUPERMUX
- DEDICATED 9600-BAUD COMMUNICATIONS

ONE UNIGRAPHICS HARDCOPY UNIT WITH MULTIPLEXOR AND TWO SOFT INTERFACE CABLES

ONE CALCOMP 1065 72-INCH PLOTTER

- CALCOMP 1065 CONTROLLER
- PLOTTER INTERFACE CABLE
- UNIGRAPHICS PLOTTER SOFTWARE

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LBNS

FIGURE 9

UNIGRAPHICS DESIGN STATION

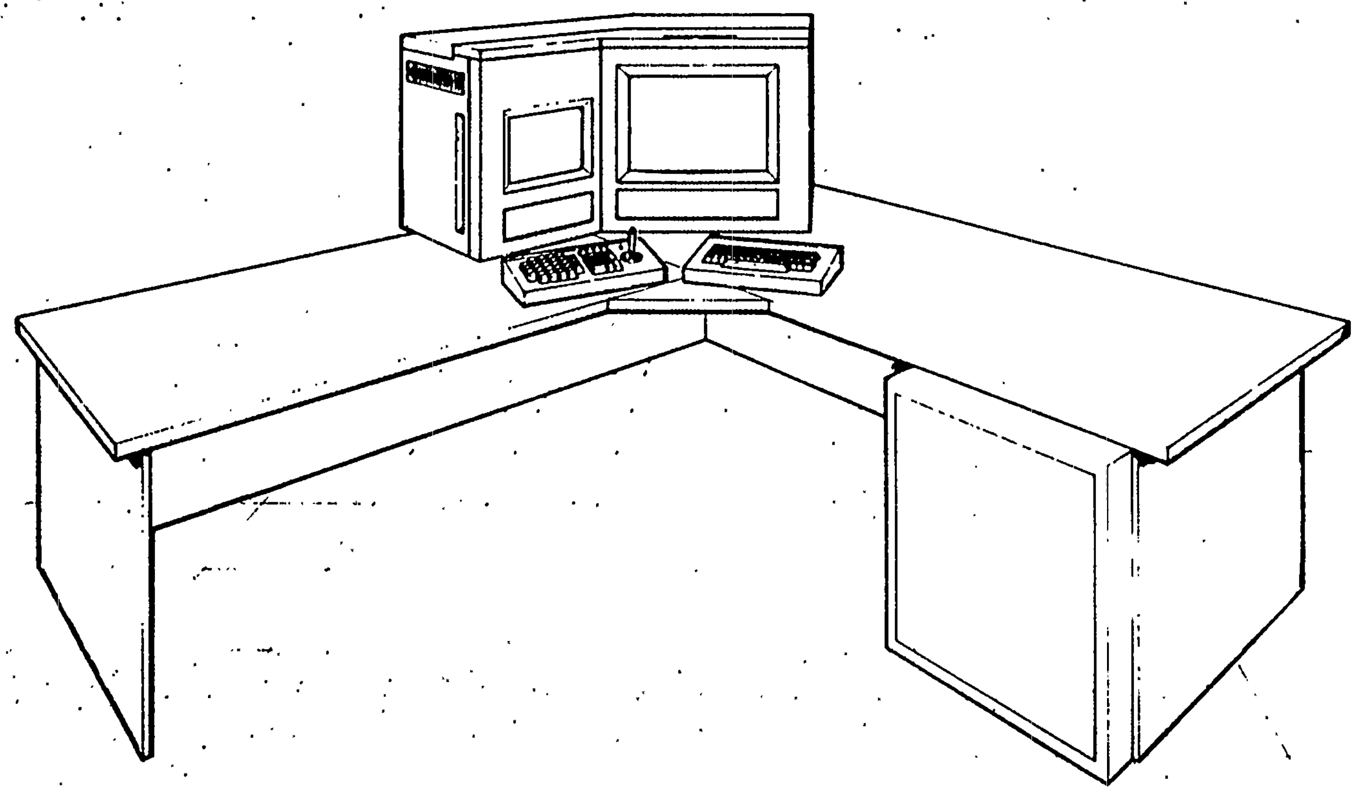


FIGURE 10

LBNS

monochromatic storage and color raster types with a resolution of 1024 rows and 1024 columns,

Experience of about (2) years of operation by a variety of users has been that the System CRT's are tolerant towards the user in that longer continuous sessions can be ustained because the image viewed is flicker free.

The design and drafting capabilities of the Computer Aided Design system are ac:essed via the function selector and keyboard.. The software providing these features mounted on fast disc and is accessed via remote communications to the PDP 11/70 processor. The PDP 11/70 operating system provides each user multi-processing environment or the simulation of an independent computer. In addition to the CAD features previously listed, the system provides manufacturing features used extensively by the Production Department. All features CAD or CAM are available to all users. Within the Design Division a Computervision system "CADD 4" comprising six. work stations,two processors, vector and electrostatic plotters have been installed during 1982. The system will only augment drafting graphics capabilities; the system is in initial operation and insufficient data has been retrieved to report upon at this time.

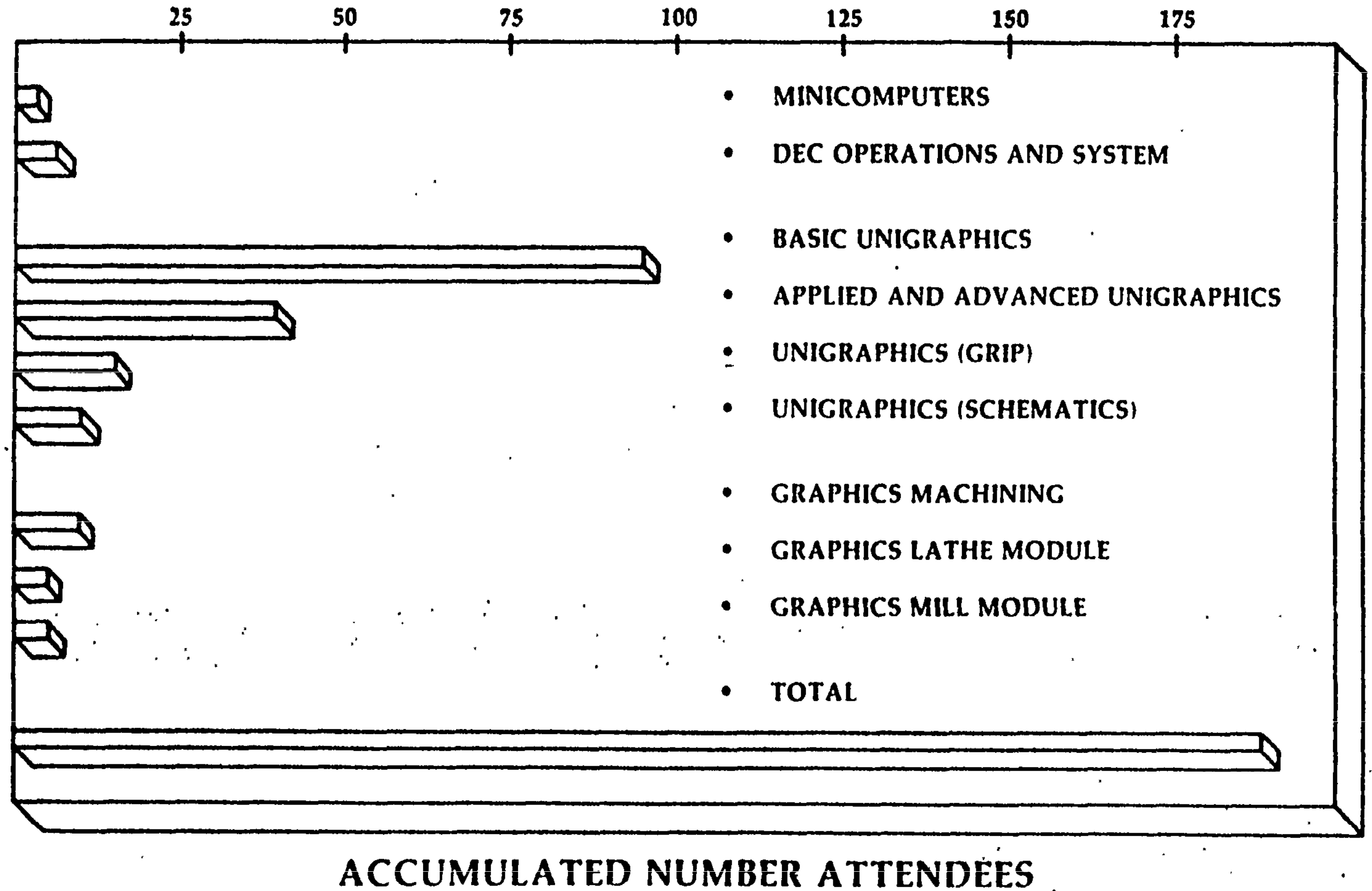
5.0 TRAINING

In preparation for the introduction of the interactive CAD/CAM system, during 1980, a training program of broadscope was structured and implemented, Some form of initial training is needed to incorporate and employ CAM and/or CAD for the benefit of the shipyard. An understanding of the technology underlying the hardware and software systems is ‘necessary. Certain specialized training is needed to develop graphics designers, parts programmers, etc. Different kinds of technical training is required in each discipline to prepare for and acquire the necessary computer system expertise for increased productivity and adherence to predictable schedules.

The objectives of the program,were to provide the shipyard users with the skills essential to effectively and efficiently operate and use the system, Special courses

SUMMARY CAD/CAM TRAINING

1980, 1981, AND 1982



LBNS

FIGURE 11

ALLIED TRAINING PROGRAM

1980 — 1982

COURSE	DAYS	TYPE PERSONNEL	PURPOSE
BASIC UNIGRAPHICS	5	ENGINEERS AND TECHNICIANS PRODUCTION PERSONNEL	SKILLS FOR AUTOMATED DRAFTING
			BASIC SKILLS TO ADDITIONAL UNIGRAPHICS TRAINING
GRIP (UNIGRAPHICS)	5	ENGINEERS AND PRODUCTION PERSONNEL	ADVANCED UNIGRAPHICS SKILLS
			SKILLS FOR CUSTOMIZING INDIVIDUAL REQUIREMENTS
SCHEMATICS (UNIGRAPHICS)	3	ENGINEERS AND TECHNICIANS PRODUCTION PERSONNEL	SPECIALIZED UNIGRAPHICS SKILLS
			EASE OF PRODUCTION OF SCHEMATIC DRAWINGS
			ABILITY TO CREATE SYMBOLS AND SAVE FOR LATER USE

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FIGURE 12

ALLIED TRAINING PROGRAM
1980 - 1982

COURSE	DAYS	TYPE PERSONNEL	PURPOSE
INTRODUCTION TO FASTDRAW (AUTOMATED GRAPHICS)	1	ENGINEERS AND DESIGNERS (STRUCTURAL)	FAMILIARIZATION AND INTRODUCTION TO CAPABILITIES INFORMAL ASSISTANCE IN COMPLEX PROBLEM (MISER TOWER)
INTRODUCTION TO MINICOMPUTERS	4	SELECTED PERSONNEL	FAMILIARIZATION PRELIMINARY SKILLS FOR OPERATIONS
SYSTEM MANAGEMENT (DEC)	5	SELECTED OPERATIONS PERSONNEL	BASIC SKILLS FOR MINICOMPUTER OPERATIONS (DEC) FACILITATE COORDINATION
OPERATING SYSTEM (DEC)	5	SELECTED OPERATING PERSONNEL	ADVANCED HANDS-ON SKILLS FOR MINICOMPUTER OPERATIONS FACILITATE APPLICATION

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LBNS

FIGURE 13

for system operators were contracted with Digital Equipment Corporation while training in CAD/CAM software utilization for programmers, technicians, engineers, machinists, draftspersons, sheetmetal workers, loftsman and other disciplines were provided by contractor and in-house personnel. The courses were given both off-site and on-site in behalf of the users. An adjunct to the training program is the tutorial capability of the UNIGRAPHICS system that provides assistance in training and use of the system, particularly in the area of automated drafting, detail layouts, design/analysis and machining/lofting/sheetmetal fabrication. The program is summarized in Figures 11 thru 13.

Presented are the numbers of trainees according to attendance in classes.for calendar years 1980, 1981, and 1982. The trainees, especially in the basic course, were a mix of planning/production personnel. The objective is to train interfacing groups of various disciplines and job classifications together., who would utilize the common data base within the CAD/CAM system. A summary of the CAD/CAM training by function and numbers of trainees according to the combination of what was achieved at LBNS in 1980, 1981 as well as the projections for 1982 is presented in Figure 11.

The comprehensive training program has provided the shipyard with a cadre of trained personnel who are adapting to the new technical environment and growing in sophistication as their experience with the system increases.

6.0 OPERATIONS

All work stations both in design and production are scheduled on a nominal single shift seven (7) hour operational basis, with second shift and weekend operations on demand. Currently, demand has risen to ten (10) hours per day plus Saturday operations. The numbers of work stations are inadequate to satisfy demand and additional equipment is justified by the overtime requests, productivity enhancements,as well as the random requests for retrieval and alteration of drawings stored in the information base. Observations over the past year,of the utilization pattern in our non-dedicated user environment indicate that during the scheduled shift, a station is 85% active, this

LONG BEACH NAVAL SHIPYARD

CAD/CAM SYSTEM

PRODUCTIVITY RATIOS

FUNCTION	RATIO
DESIGN/DRAFTING	UNIG./CONV.
INITIAL DRAWING	1.5 TO 1
DRAWING REVISION	10 TO 1
BILL MATERIAL/GENERAL NOTES	10 TO 1
MACHINE SHOPS:	
MILLING MACHINE PROGRAMMING	4 TO 1
LATHE PROGRAMMING	8 TO 1
STRUCTURAL SHOPS:	
PUNCH MACHINE TAPES	3 TO 1
FLAT PATTERN DEVELOPMENT	6 TO 1
DUCTING, OTHER PARTS	6 TO 1
LOFTING	

TABLE 1

can be construed as full use of the station. table I shows the productivity ratios. achieve in the various areas serviced by the system; the productivity ratios have been arrived at by statistical comparison of manual as opposed to automated operations.

The system within the shipyard is currently in process of being expanded by the addition of nine UNIGRAPHICS work stations, a DEC/VAX 780 minicomputer and 8 personal microprocessors. The expansion includes an augmentation of five stations in the structural group with 'four additional stations in the Design Division. Justification for the expansion is provided by the recorded utilization, audited productivity enhancement, and projected demand. The need for the system expansion was rapidly recognized as the diverse-users became familiar with the system, the software and concommitant with this experience factor the demand for work stations increased as more work was placed on the system by various managers. Another conclusion drnwn is the need for a dedicated second shift in the Design Division to perform routine drafting and designer support.

The availability of the system has been about 98 percent. We have experienced two unscheduled outages of short duration and these have been mechanical failures, A communication link has been established with the DEC diagnostic center in DENVER. At any initial indication of hardware/software problems the DEC center is alerted, and in turn the local DEC maintenance center is informed to correct the incipient deficiency during the scheduled downtime before a failure occurs.

The major recommendations arising from the analysis of the data for 1981 thru 1983 are that advanced training of personnel continue, increase participation of all areas of the shipyard to gain maximum benefits, and that an integrated system is essential for maximizing the *cost* return on the investment required for installation of a graphics system and the training to achieve true CAD/CAM.

7.0 PROJECTED PROGRAMS

Figure 14 presents a summary of the projected program elements for continuing and enhancing operations of the shipyard computer support system. By the use of

special optics technology merged with computer graphics a system now in development will be capable of performing a fully automatic 3-dimensional optical scan of ships interior compartments 'and systems. The retrieved data properly processed will provide a complete 3 dimensional description of the scanned surfaces and the systems contained within the area. This process will create "as built" configurations of ships interiors with significant improvement and savings accruing to the repair and alterations embarked upon.

Another significant development will' be the evaluations of a non-contact scanner for propellor inspection. This system will enable rapid and very accurate determination of discrepancies between propellor design data and the condition of the in se-vice propellor, an important consideration in drive/noise efficiency.

The Numerical Control (N/C) parts library of programmed parts now exceeds about 3090 and with new N/C tool control technology utilizing'microprocessor system, a Direct Numerical Control System is proposed for installation on selected machines. Figure 15 illustrates schematically the proposed system. Under control of the parts programmer (process planner) machines will be scheduled and programs together with pertinent information downloaded to the CNC controllers. In turn, this procedure will eliminate, to a degree, the use of control tapes; and permit modification and/or editing the part program at the tools themselves.

The training program for design and production personnel is expected to continue. Emphasis will be placed on increasing the depth of knowledge and sophistication of the trained users-in order to fully exploit the potential of the system.

The LBNSY shops CAM operations and the Design CAD operations have evolved in discrete modules over the years. Each step has been planned, implemented, and supported in timely fashion to produce increased productivity.and other benefits; CAD/CAM program support had to be provided to all components using the system as: training, technical support, project guidance, industrial engineering, operations

PROJECTED PROGRAM ELEMENTS

EVALUATE FEASIBILITY AND APPLICATION OF SHIP SURFACE SCANNER/DIGITIZING SYSTEM

EVALUATE FEASIBILITY OF NONCONTACT SCANNER FOR PROPELLER INSPECTION/REFIT PROGRAM

CONTINUE DEVELOPMENT AND IMPLEMENT METHODS AND PROCEDURES FOR COMPUTER-AIDED DRAFTING/ DESIGN/MANUFACTURING

CONTINUE DEVELOPMENT TRAINING PROGRAM — PLANNING/PRODUCTION PERSONNEL IN COMPUTER-AIDED DRAFTING/DESIGN/MANUFACTURING

SUPPORT NAVSEA SELECTED PROGRAM DEVELOPMENTS

- N/C POLICY
- COMPUTER-AIDED DESIGN/MANUFACTURING
- DATA INTERCHANGE AND DATA BASE DEVELOPMENT
- DIRECT NUMERICAL CONTROL FOR N/C MACHINES
- INTERFACE WITH OTHER SHIPYARDS
- SOLIDS MODELING

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LBNS

FIGURE 14

SYSTEMS INTEGRATION PROJECT

UNIGRAPHICS & OTHER SOFTWARE SYSTEMS

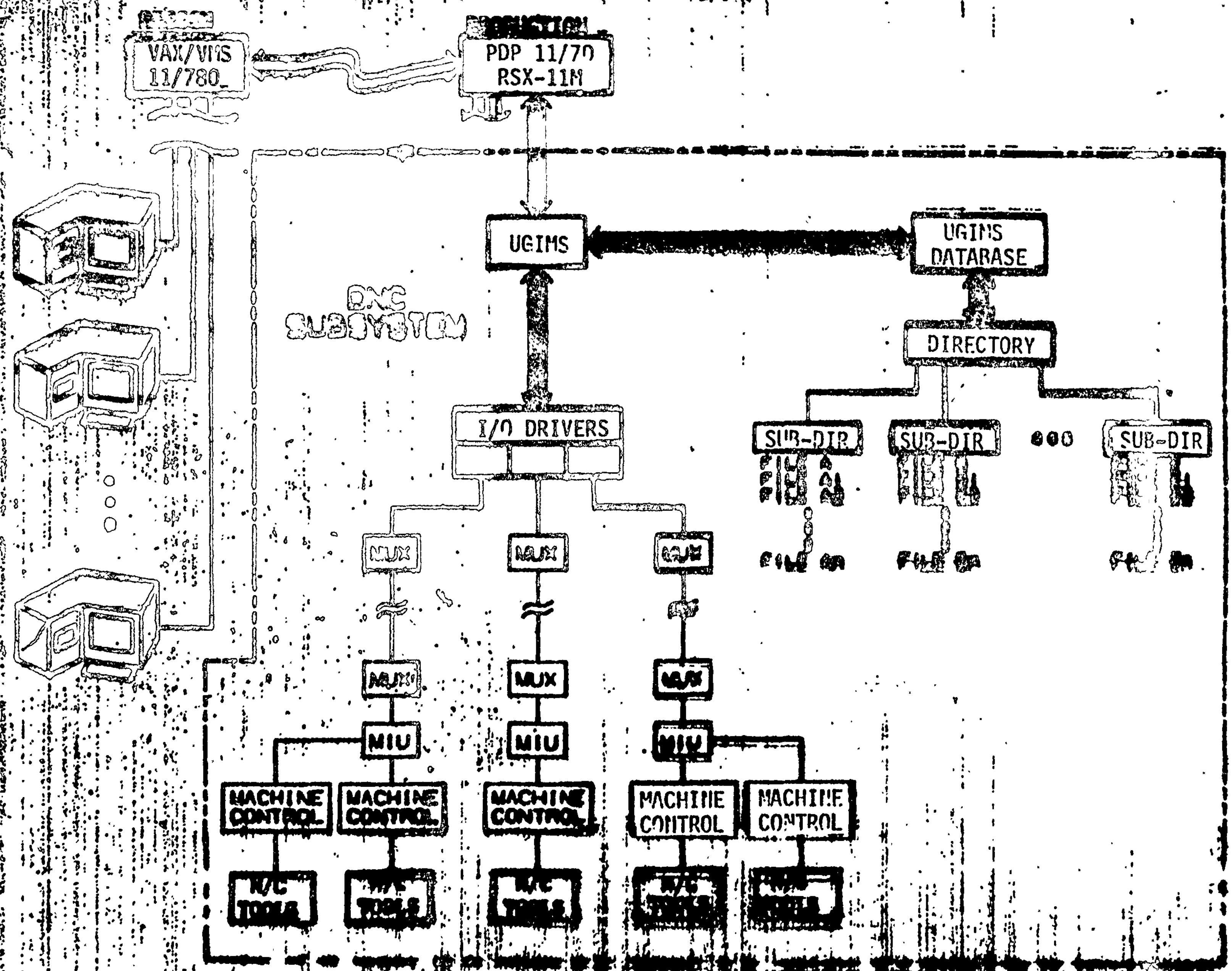

FIGURE 15

research as needed,

In order to effect transfer of information between the CAD/CAM.systems of LBISY and other yards in a cost effective way requires an implementation plan with milestones to be achieved, It requires a project manager and shipyard management support in order to achieve the success similar to the computer network now implemented at LBNSY. It will require:

(a) Establishing two large computer centers with an interconnecting network, as' illustrated in Figure 16.

(b). Establishing management requirements for the control of such a system.

(c) Establishing specifications, procedures, and techniques to 'obtain a total system,

(d) Establishing the operational control requirements for participation in the total system,

8;0 BENEFITS

Briefly, the benefits of CAD/CAM through the use of Numerical Control (N/C) to manufacture parts and in design and drafting are:

Lower cost Parts

Higher Quality Parts

Part.Uniformity

Closer Tolerances

Shorter Delivery Times

Production of Complex Parts (not possible in manual mode)

Decreasing lead time for programming and process planning-

.Increases designer effectiveness

Decreases delivery time of final drawing

Provides optimization of the design function by permittihg evaluation of alternatives

BENEFITS - Continued

Integration of the system decreases turn-around-time from design to completed/ finished job

Permits designer to perform extensive analysis rapidly

Productivity increases because all machine functions are controlled automatically.

Therefore metal is cut a greater percentage of the overall machining time.

Storing and handling bulky jigs and templates is eliminated because they are replaced by tapes, punched cards,' or Direct Numerical Control (DNC) in the near future'.

Jobs can be set up faster because guiding fixtures for newly.designed parts do do not .have. to be designed and manufactured.

Repeat orders can be produced quickly because the tapes have already been made.

Enginerring changes to workpieces can be readily incorporated simply by changing instructions on the tape.

Quality control is better because N/C machines are more accurate and can produce closer tolerance parts. This means fewer parts are rejected and the amount of scrape is reduced.

Parts handling can be reduced because more operations can be done by an N/C machine with one setup than by a conventional machine.

BEHAVIOR MODIFICATION OR WORKER PARTICIPATION?- PRODUCTIVITY AND THE SHIPBUILDING WORKFORCE

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National Academy of Sciences
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Dr. Gaffney, a social scientist, is a senior staff officer at the Marine Board, National Academy of Sciences, where he continues to combine his research interests in the organization of work with a long standing involvement in the maritime industries. Dr. Gaffney has conducted a number of field research projects on the social and work organization of American and Canadian fishermen and seafarers. He has also conducted simulator-based research at MarAd's Computer Aided Operations Research Facility (CAORF). One particular interest of Dr. Gaffney has been industrial experimentation with new forms of work organization for purposes of improved productivity, safety, and job satisfaction.

Dr. Gaffney is a graduate of the U.S. Merchant Marine Academy, New School for Social Research, and Ohio State University. He has authored a number of papers on the topic of alternative organizations of work onboard merchant ships and within shipyards. He has also organized seminars to enable U.S. ship operators and shipbuilders to meet their domestic and overseas counterparts and researchers who are actively engaged in organizational change.

The views, opinions, and conclusions expressed in this paper, unless specifically referenced in the text, are represented to be those only of the author.

ABSTRACT

For the past two years, the IREAPS Symposium has been host to a controversy surrounding the topic of maximizing human resource contributions to shipbuilding productivity, Two *schools of thought have been presented (Behavior Modification; Anderson (1981, 1982) -- and -- Worker Participation; Bradley (1981), Gaffney (1982), Harper (1982), Lucie & Fisher (l982).*

Although Anderson has presented his case for behavior modification against a backdrap critique of worker participation/organizational change efforts, no corresponding criticism of behavior modificatian has yet been made by the other school. This paper will review the two approaches, specifying their respective strengths and weaknesses.

INTRODUCTION

For the past two years. the IREAFS Symposium has been host to a quiet controversy surrounding the topic of maximizing human resource contributions to shipbuilding productivity. The two contending approaches might be variously titled. but are here characterized as 'Individual-focused“ vs. “group-focused”. To be more specific, the "individual focus" school equates with “human performance engineering", a form of organizational behavior modification as proposed by Anderson (1981, 1982). The “group focus“ techniques entail a much wider range of organizational changes ranging from quality circles to semi-autonomous work groups and multi-skilled workers. Gaffney has reviewed these under the twin heading of “worker participation and organizational change" (1982) though more detailed treatment of specific group-focus innovations are found in Bradley (1981), Harper (l982). and Lucie & Fisher (1982)

The controversy has been quiet in the sense that within the symposium it has been confined largely to the papers and has not generated much discussion from the floor or over evening drinks. But the issue has been raised in other shipbuilding productivity forums: the National Academy of Sciences Committee on Navy Shipbuilding Productivity, the Human Resources Panel of the IREAPS/SPC 5-Year Plan, the Blue Ribbon Committee of the Ship Production Committee, and the recently held SP-9 Workshop on Shipbuilding Social Technologies. Many yards are experimenting now with group-focused approaches. and it has been proposed that a cooperative effort take the form of a new (or revitalized) panel of the SPC. Which means that individual yards (and possibly the Ship Production Committee) are, or soon will be. in

a position of making choices as how best to invest in human resource productivity initiatives.

Anderson has recommended strongly in the favor of behavior modification interventions and has, in both papers, made his case *for* human perfornmance engineering in the context of an argument *against* the group-focused techniques. The corresponding case for the group-focused techniques has been made by Bradley, Gaffney, Harper, Lucie & Fisher, but with no corresponding critique of the behavior modification approach.

This paper is intended to restore a balance to the discussion by reviewing the behavior modification technique from the point of view of a proponent of group-focused innovations, and by answering the charges leveled by Anderson at that latter approach. What will not be attempted in this paper, is a detailed review of the need for, and gains realized by. worker participation and organizational change projects in shipbuilding and other industries throughout the world. That information is contained in Gaffney (1982). Nor will there be an extended discussion of the techniques and claims of behavior modification. That can be found in Anderson (1981).

DEFINTIONS

Especially for those readers who may not be familiar with individual or group-focused human resource/productivity innovations, a review of terms is in order.

"Human performance engineering" is an individual-focused productivity improvement technique. the ingredients of which:

> start with a precise statement of desired company objectives in terms of behavior changes that may be required of individual workers. An accurate and reliable behavior counting system is needed next to learn exactly what workers are doing so that graduated steps toward' the final behavioral adjustment can be planned. A feedback system in the form of individual. public charting is then to be introduced. Following a suitab1e period, a potent and relevant positive consequence consistently should be given for behavior increases or for maintenance of an acceptable performance (Anderson 1982: 335).

Anderson's "human performance engineering" is a proper name for his version of "organizational behavior modification" which contains the same basic elements of (1) explicit behavioral objectives, (2) close monitoring of performance, (3) performance feedback to the individual whose behavior is being modified, and (4) positive reinforcement for acceptable results. These basic principles of organizational behavior modification are extensions to the human sphere of knowledge initially gained from learning experimentation with animals in laboratory settings. E.F. Skinner is the best known of this "behaviorist" school of experimental psychology.

"Group-focused human resource/productivity innovations" cannot be so neatly defined as "human performance engineering" or even "organi zational behavior modification". That is because the term, "group-focused ..." is introduced here only for purposes of this discussion and because it covers a wide range of techniques and approaches which are not necessarily uniform in their objectives or application, and which may be mixed and matched according to the requirements of individual industrial settings. popular names for these group-focused work improvement programs include quality of work life, organizational development, and socio technical systems. These terms refer principally to the process or framework of change rather than to the specific content of innovations that may be found in any particularl setting. Consitituent elements frequently consist of joint labor/management committees, quality circles, semi-autonomous work groups, multi-skilled workers job redesign, organizational restructuring, flextime, and gainsharing plans (Scanlon, ESOP, etc.).

POINT/COUNTERPOINT

Apropos to the rebuttal nature of this paper, the principal discussion wi11 take the form of a series of responses to those charges made by Anderson in his 1981 and 1982 presentations,

Charge #1 Group-focused programs are mired in speculations on the importance of workers' internal mental states while behavior modification efforts are concerned only with objective observable environmental conditions and worker behavior (actions).

Anderson specifically charges that the group-focused programs noted above:

rest heavily upon antecedant means to change work performance. By "antecedant" is meant various putative non-performance features of the person -- such as internal state, condition, or mental process -- must be altered as a prerequisite to work change. As examples, certain of these work-improvement programs variously are dedicated to increasing "committment" (the antecedant state) to specified goals, "intentions/convictions" to work harder/longer, positive "feelings" about job and/or company, and so forth. These alleged antecedant-state changes are seen as propadeutic (preliminary - MEG) to improved work. They are antecedant 'in the sense of being precursors to the desired performance (Anderson 1981:339).

... any work-improvement program will be successful the degree to which it is directed at the actual actions of employees, not at such inferrables as personality traits, motives, attitudes. or other so-called internal or "mental" characteristics. Indeed there is considerable scientific evidence that the latter, by whatever definition, more likely will change as a result of behavior changes rather than serve as the cause(s) of human action.

This is a classical behaviorist argument that behavioral scientists (and managers) should not be concerned about theoretical internal states such as (committment, intentions, convictions, feelings) but rather concentrate on the relationship between observable behavior and the environment which conditions it. Behavior is shaped more by its consequences than by antecedent states, and what is needed is movement away from fuzzy postulation of internal processes toward a true objective science of behavior. Skinner notes that the physical sciences such as physics and biology:

... did not advance by looking more closely at the jubilance of a falling body, or . . . the nature of vital spirits, and we do not need to try to discover what personalities, states of mind, feeling, traits of character. plans, purposes, intentions, or the other prerequisistes of autonomous man really are in order to get on with scientific analysis of behavior (Skinner 1971:15).

Response #1 Without agreeing that mediating internal states (values, feelings, goals) are inconsequential to the behavior of human beings in work settings (after all, the behavior of people in organizations is far more complex than that of dogs, pigeons, or rats in laboratory environments), it must first be pointed out that Anderson is simply incorrect in his assertion that these group-focused programs" ... rest heavily upon antecedant means -- internal state, condition, or mental process -- to change work performances."

In fact, proponents of such group-focused innovations as autonomous work groups, multi-skilled workers, gainsharing plans, and quality circles are concerned with internal states only as a by-product of objective organizational change and performance improvement. William F. Whvte, who has been a very active group-focused researcher and practitioner writes;:

> As a longtime consultant and researcher in industry, I often come in contact with the executive who has just discovered the importance of "the human element." "What we must do is change people's attitudes," he usually says. As politely as I can. I tell him to forget attitudes. The problem is to change the conditions to which people are responding. If he does that, people will behave differently and he will find that attitudes -- if they still interest him -- will adjust themselves to the new situation (Whyte 1972:67).

Any sophisticated proponent of worker participation and organizational change programs would argue right alongside Skinner that behavioral scientists (and managers) should abandon their preoccupation with the inner life of man and concentrate on the relations between man and environment.

Anderson's critique could appropriately be leveled at "pep-talk" and "sensitivity session" approaches to productivity improvement (where the object is to first change attitudes which will hopefully later change performance), but this isn't the sole target Anderson identifies. He also includes autonomous work groups, organizational restructuring, flextime, job restructuring. and worker participation in his charge of mental process speculation. However, these latter innovations don't rely upon the formation of antecedent mental attitudes leading to desired behavior. They rely upon very concrete, directly

observable, environmental changes to accomplish that end. Anderson has ignored the advice of his cited experts (Woodman & Sherwood, 1980) and has confused T-Group training (sensitivity training) with team development. They are not the same thing, and he mistakenly paints all with the same brush.

Charge #2 Group-focused work improvement programs do not rest upon firm empirical evidence.

Anderson claims that evidence is lacking both for the internal and external validity of group-focused work improvement programs. The internal validity issue has to do with proving that change has occured in the internal states of the worker (commitment, job satisfaction, espirit do corps). Anderson feels that:

> Clearly, without firm information of this kind, there would be little value in assessing whether the program under question influences external measure5 of importance to the organization per se (1981:339).

Response #2 Following the response to the first charge, there has been no need to demonstrate the internal validity of a model of antecedent mental states that has not been postulated by worker participation and organizational change proponents. Since they make no claim to the importance of such internal processes they would naturally not attempt to demonstrate that they were either present or active.

Which leaves us with the matter of external validity.

Charge, cont.

> The second question to be answered thus is whether the program actually improves some aspect of human work . . . the “proof of the pudding” so to speak. Again, while there have been many claims that each does, i.e., decrease costs, or waste. or withdrawl, increases productivity or quality, rigorous evidence is . . . sparce (Anderson 1981:340).

Response, cont. The key issue here is summed up in the word "rigorous." Organizational behavior modification is the child of

experimental psychology which operates according to rules of evidence very similar to those employed by the laboratory physical sciences. Evidence which would be acceptable within other branches of the social sciences, not to mention the quality of experience relied upon to guide the action of industrial managers. is frequently not good enough for experimental psychologists.

But it is not the case that other varieties of psychologists. and sociologists, anthropologists, and managers have insufficient or inappropriate standards of evidence. They are quite proper for the level of system analysis in which they are respectively engaged. A rigorous experimental design is fine for investigating a very discreet piece of behavior in which the subjects and independent and dependent variables can be carefully circumscribed. It is equally out-of-place in investigations and analyses of complex settings involving many interacting subjects, and multiple independent and dependent variables.

Behavioral scientists and managers engaged in group-focused work experiments are generally more interested in achieving positive results than in formally proving or disproving the efficacy of any particular element of the change program. That is why this type of research is called "action-research". If midway through a program, even one designed as a quasi-experiment, it appears that one or more innovations is not producing the intended results, or is working against the objectives of the program, they are eliminated. This, of course, ruins any purity of experimental design that may have been provided-for at the outset. But nobody is very concerned because it is understood that rigorous evidence of the sort that would convince an experimental psychologist is nice but not necessary. The social scientists. workers, and most importantly the managers that live with these work improvement programs are quite satisfied that they know what is. and what isn't. working.

In support of his claim that group-focused work improvement programs show no evidence of success, Anderson cites the Cummings, Molloy, and Glen critique of 58 selected work experiments (1977). Al though Cummings et al do conclude that the research literature on group-focused experiments is weak in terms of formal validation, they understand and are sympathetic to those reasons for this lack of hard evidence:

> Those researchers who have complete control over the scheduling of treatments are able to control for most threats to validity. In the studies examined in this review, however, the researchers did not have complete control over the scheduling of their treatments (Cummings, Molloy, and Glen, 1977:688-9).

> The 58 studies fared badly when assessed against the evaluation criteria used in this critique, Perhaps using other criteria such as applicability of the studies to organizational change, relevance to those engaged in work improvement programs, and degree of understanding of organizational change processes, the studies would have been judged stronger (1977:702).

> The critique has been made with full awareness of the difficulties that face the researcher who tries to formulate a strong design for experiments in this field: for instance, there are few if any instances in which research goals have predominated over and had equal status with pragmatic objectives, such as increasing performance (1977:702).

And that is the key point, that "... there are few if any instances in which research goals have predominated over and had equal status with pragmatic objectives, such as increasing performance". The researchers, consultants, and managers who have been engaged in group-focused work programs have been more interested in pragmatic results than methodological purity. Guilty as charged.

But the lack of rigorous evidence for program success is not the same thing as evidence of program failure or even lack of non-rigorous evidence for program success. And neither Cummings et al (1977) or Woodman and Sherwood (1980), Andersons two cited experts, make this claim. They conclude only that the subject work experiments were found lacking in methodological rigor, an unsurprising finding in view of the fact that the authors of these studies never attempted to meet these criteria. The recommendation from both the Cummings et al and Woodman and Sherwood critiques? Improved research designs. Additionally, Cummings et al note considerable informal evidence (some of it their own) of group-focused program efficacy:

> Recent reviews of these studies attest to the overwhelming number of positive results that have been

reported in the literature (Taylor, 1972, Birchal & Wild, 1973, Srivastava, Salipante, Cummings, Notz, Bigelow, Waters, Chisholm, Glen, Manning, & Molloy, 1975) [Cummings et al, 1977:676].

It is noteworthy that Anderson does not provide one shred of information that suggests that group-focused innovations have not worked, only that they are "... at worst. unproven" (Anderson 1982:562).

On the subject of 'research methodology. it is relevant to point out that the National Shipbuilding Research Program has never aspired to such formal rigor, As pointed out by Garvey in an address to the 1982 Conference on Industrial Science and Technological Innovation:

> I (wish to) clearlv establish that the program was not intended to be a research program in the conventional sense. The program was intended, from its original inception. to improve the productivity of U.S. shipbuilding (1982:2).

Charge #.3 Group-focused work innovations have limited application.

> ... even were the evidence both greater and of better quality regarding both the internal and external validity of these approaches. each poses the further untested concern of general applicability. Clearly, any program of work improvement will be of interest to productivity experts the degree to which it readily can be adapted to the manifold work settings that prevail in our complex culture. Unfortunately, many of the (group-focused) strategies, even if ultimately proven externally valid, seem quite limited in this connection. For example, autonomous work groups and job redesign likely have quite restricted application because of the larger problems they pose for organizations restructuring and overhaul, materials handling, and so forth (Anderson 1981:340).

Response #3 Nobody said it was going to be easy. The problems faced by the shipbuilding industry are large and solutions (both of a human resource and engineering nature) will not likely be painless. For many yards, the changes will entail organizational restructuring and overhaul, and modification of materials handling practices anyway. This is the direction being dictated even in the absence of group-focused work improvement programs. So it is more a question of molding new forms of work organization to new production technology and processes which are already being introduced. The relationship of group-focused innovations to major organizational and technological restructuring is an indication not of the limitations but of the promise of this type of intervention.

But what does Anderson say about the applicability of human performance engineering? He first recommends that considerable time be spent in locating where best to begin an application within an organization. One specification has to do with the ease of program institution and development. To be avoided are *work* settings involving:

> ... complicated tasks. large and “rambling" work areas, and a history of workers and/or manager resistance (Anderson 1982: 566).

Which sounds like a shipyard. Such environments are not conducive to the application of a technique that requires:

> ... a precise statement of desired company objectives in terms of behavior changes that may be required of individual workers . . . an accurate and reliable behavior counting system to learn exactly what workers are doing . . . a feedback system in the form of individual, public charting (of performance of specified behaviors) . . . and (consistent) consequences for . . . increases or for maintenance of acceptable (specified) behaviors (Anderson 1981:335).

Presented in the form of a choice, should the shipyard manager prefer to invest in a behavior modification program that promises scientifically rigorous proof of effectiveness in rather

limited applications? Or should he invest in a quality of work life program that attempts to achieve major modifications of work practices and organizational boundaries that stand in the way of new technology and production processes -- but offers only the standard sort of quantitative documentation and qualitative experiential evidence of program effectiveness that he. as an industrial manager. is normally accustomed to evaluate? Chances are that he is not so worried about rigorous scientific proof as he is concerned that his major productivity problems are being addressed. But what are his major productivity problems?

First it is necessary consider precisely what it is that we mean by "productivity"; and its relationship to human resources. John kendrick, perhaps the nation's leading productivity expert, draws the following important distinction:

> When the term "productivity" is used in a very narrow sense to denote labor efficiency, as revealed by work measures that compare actual output to engineered standards (or the time required to perform a given tasks or to produce given outputs relative to a standard), the significance is clear. How do we train. manage, and motivate worker5 to achieve a high degree of efficiency in their work (kendrick 1977:307)

> Occasionally, "work measures" are confused with productivity measures. But work measures relate actual output to a norm, or standard, They thus measure levels and changes in efficiency under a given technology. They are not measure5 of productivity, which reflect changes in technology and other factors in addition to changes in labor efficiency as such (Kendrick 1977:13).

> When productivity is defined broadly . . . as a relation of output to all resource inputs, human and nonhuman, the relationship of productivity to manpower seems more tenuous; but it is far more pervasive and profound. "... (T)he greatest challenge to the human factor is how to economize on using all resource inputs per unit of output; that is, raising total tangible factor productivity. This involves innovations in the Ways and means of production: creating, adopting or

> adapting, and applying new technologies, organizational forms and work methods, processes, and techniques in order to obtain greater results from the same real cost. This involves human beings at their most creative, imaginative, and ingenious level. Al though we generally think of innovation as being a distinctively management, entrepreneurial function, it involves the workforce at all levels. The best managers build organizations that elicit creative ideas from workers generally and involve them in the innovative and adaptive activities connected with technological progress (Kendrick 1977:3-4).

Which returns us to the earlier question -- what are the shipbuilders major productivity problems?

If they are primarily problems of labor efficiency (productivity in the narrow sense of the term), then the behavior modification approach may be indicated. But if the shipbuilding industry's productivity problems are broader than that, and require the raising of total tangible factor productivity, then group-focused programs entailing worker participation and organizational change are more appropriate.

Aside from an uncited reference to a study that compared the number of minutes actually worked per hour of pay by the average American and Japanese worker (Anderson 1982:557), Anderson gives no information as to the significance of labor efficiency to U.S. productivity ill in general, and absolutely no hint as to the significance of labor efficiency to the productivity of the U.S. shipbuilding industry. On the other hand, a number of analyses of American shipbuilding conducted by Americans, Japanese, and Europeans, have consistently pointed to the need to modify the manner in which we use our shipyard workers (hourly and salaried) -- specifically in the direction of worker participation, semi-autonomous work groups, multi-skilled workers, and minimization of bureacratic organizational boundaries (see Gaffney 1982). It would appear that it is not sufficient for the American shipbuilding workforce only to work harder, they must work smarter.

Since Anderson has not presented any case for the need of behavior modification in shipbuilding (he hasn't shown what's broken in that industry that behavior modification is particularly good at fixing), his argument rests solely on the demonstration of that technique's methodological rigor (and the lack of such rigor in other approaches). Considering that we do have good information that shipbuilding's human resource/productivity problems lie largely in another direction, this brings to mind the anecdote of the poor soul looking for his

lost wallet under the illumination of a streetlight a hundred yards distant from the corner where he knows he dropped it. Asked why he was pursuing his search so far away from that location, he replies, "Because here the light is better”.

Anderson argues two cases in his 1981 and 1982 papers. He presents the case for behavior modification and also the case against all other work improvement programs. He concludes that there is only one “management style” that succeeds in addressing the human resource side of productivity (that of human performance enginering) and that, therefore, all manager5 should become human performance engineers (1982:558,565-6).

In fact, Anderson demonstrates only that:

1. Behavior modification may be an effective technique in certain applications requiring improved labor efficiency. and that

2. Other human resource/productivity techniques are generally applied in the absence of formal experimental designs.

So what does this mean for future human resource innovations in shipbuilding?

It does not mean that there is only one appropriate management style -- and that it is behavior modification. It does not mean that yards should abandon exisisting or planned program5 in worker participation or organizational change.

It does mean that behavior modification may be usefully employed within shipbuilding to remedy problems of labor efficiency. Should some yard (or the industry as a whole) identify a substantial labor efficiency problem, then behavior modification should be given a try.

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HUMAN FACTORS AND MODELS

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I. ABSTRACT

It is interesting to speculate what might happen if an industrial plant or ship were to be constructed to conform to the requirements of a system designed to maximize the human's potential.

The concept of this system embodies the basic assumption that man should be considered one of the major components of the system rather than merely an operator of the system once it is developed.

Some way must be found for thinking about the functions of the man within the framework of the man-machine-software environment.

Design Work Study Technology and physical models are tools which enable the system engineer and designer to study all aspects of the operation and design by making use of the models to study man-machine-software interfaces.

II. INTRODUCTION

In recent years, there has been a renewed interest in human factors considerations. This is partially due to the Three Mile Island incident, and somewhat to the Space Shuttle Program where human factor problems have been discovered after design and construction was completed, and to the concern by the Navy that some of today's military systems cannot be properly operated and maintained.

Joe Castle presented a paper at the SNAME Star Symposium entitled "Human Factors in Naval Ship Design." It was pointed out in his paper that inadequate consideration of human factors exist in ship design. One of the proposed solutions to this problem was to increase human engineering feedback early in the design process to ensure adequate consideration of human factors throughout design and acquisition.

Experience indicates that the more involved the owner or operator of the plant or ship becomes in the design phase, the better the chance that the design will pay greater attention to human engineering aspects.

So, what is this so-called renewed human factors activity all about? It is a field born after the Second World War. It places emphasis on the efficient and safe utilization of man and man-machine-software systems with the selection, design and arrangement of system components. As systems design progresses through a series of stages and sequential processes, different activities on the part of human factors engineering are required (see Slide 1).

This paper will address each of these areas of responsibility and describe some of the procedures used to develop operational concepts which can be or are used in conjunction with scale models or full size mock-ups for space allocation and machinery arrangement studies.

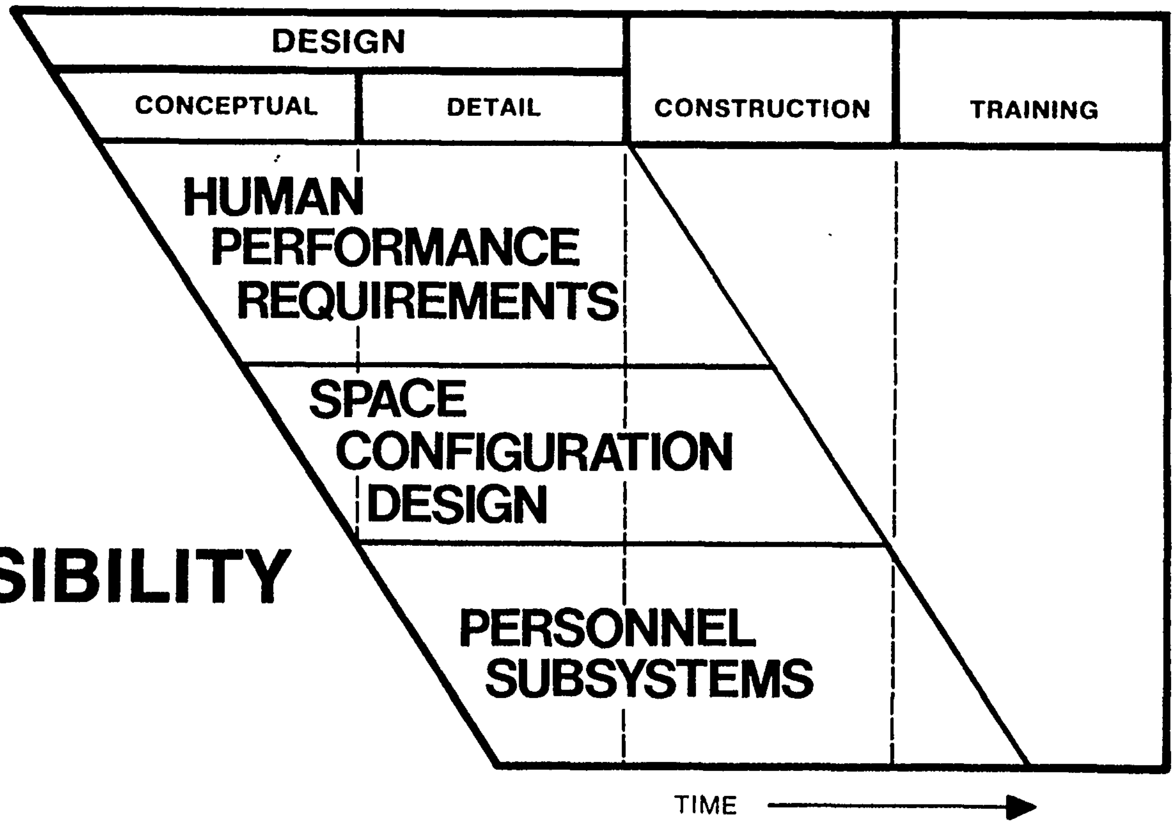
III. HUMAN PERFORMANCE REQUIREMENTS

How man is accommodated in highly complex environments is a problem the Navy faces in its design of shipboard systems. The design process itself must consider men from the outset, since the system is a part of a total habitat which must be lived in for many months at a time yet still perform as a system.

This segment of the paper deals with human performance not in terms of its anthropometric aspects, but how the individual operator is integrated into the evolving combat system design. This segment also deals in models but models of a different sort than are addressed elsewhere; models which exist first as a mental construct in the mind of the combat systems engineer as he mentally exercises a tactical operational scenario through, for instance, a sequence of operational events. His models identify the actors (man/machine/software) and what combination of, or sequence of actions, that must transpire to cause the model to perform. These conceptual mOdels take the form of the applied techniques of functional analysis, Functional Flow Diagrams (FFDs) and Operational Sequence Diagrams (OSDs). Taken all together, these techniques provide a structured basis for developing overall system tasks and constitute a Task Analysis for each individual operator in the system. For instance,

HUMAN FACTORS ACTIVITY IN THE SYSTEMS DEVELOPMENT CYCLE

AREAS OF RESPONSIBILITY



SLIDE #1

extracting the columnar information from an OSD in an operator column describes a sequence of actions an operator must take in accomplishing his Job, or Task. In a similar fashion, extracting the columnar information from an equipment *or* software column describes the tasks which must be performed by the equipment and software system operating in concert with the human operator. During the course of this conceptual modeling effort, certain operator-to-operator, operator-to-software, operator-to-equipment and equipment-to-equipment relationships are established which when interpreted prescribe or dictate adjacencies which must be satisfied in the modeling effort associated-with the physical space configuration design. At this point, the human factors engineer examines the tasks as generated by the analysis, aided greatly by the modeling effort and prior consultation with the combat systems engineer, to determine their feasibility for human accomplishment and apply anthropometric data to the design of the shipboard space such that the environment created by both Task and Space are compatible with their human interface. Shipbuilders will recognize that the techniques and products addressed herein are contained in the bid package and are used as technical input in the formulation of bids responding to requests for procurement of major systems.

Introduction to Human Factors Engineering for Combat Systems

History could provide many examples where little attention was given during system development to human functions and requirements. World War II brought the problem to light when considerable and critical human error became commonplace in complex weapon systems, Typically, human error was traced to:

1. Failure on the design engineer's part to consider man's limitations

2. Placing too much demand on the operator

3. Poor equipment design and layout.

A crisis in the design of combat systems was created when threat from aircraft and missiles made the transisition from sonic to supersonic speeds. Design and human engineering problems were compounded by the fact that the enemy was capable of mounting simultaneous, sustained, and massive surface, subsurface, and air attacks. Out of these crises, the concept of the integrated combat system (man-machine-software) was born, evolving partly as a result of our own advancing technology and mute recognition that the enemy had a like technological capability. Integration of systems, including man as an integrating element, was essential if threat reaction times were to be met.

Integration of systems as a design objective has always been a significant factor in combat system design, Integration in its most simplified form was initially achieved through the human interface in the form of interior communications between operators of the various subsystems. World War II combat systems are typical in this regard. Integration in its most complex form, which is still evolving, is that represented by the modern integrated combat system wherein the digital computer is the integrating element between the human operator and the operating systems. It can be seen that integration as a design objective has not changed. What has changed is the degree to which integration is extended and its level of application. Precise definition of the man-machine-software interface is the key element to effective system

integration because it is at that point (where the human operator interacts with the system) that the highest level of integration occurs. Failure to define initially this level at which integration begins (and ceases) has been a major fault of many previous designs.

Traditionally, combat system designers have viewed the problem of integration from the botton up as opposed to integration from the top down, because ultimately, in order to be effective, integration must involve the complex actions and interactions of components and subcomponents at the lowest levels of the system. As a result of this, design agents have tended to ignore, at least at the outset of a design, the human interactive element; yet it is only at this level (the man-machine-software interface) that successful system integration can commence. More as an afterthought, the human component was satisfied by providing him (the operator) with a console or equipment to monitor the operating sytems. In other words, man was viewed not as a participating agent in effective system integration, but as a passive, sometimes unruly bystander.

Human factors engineers are not, as a general rule, combat system design engineers, and because Navy combat systems are operationally defined by the threat environment, many of the human considerations with respect to the technical design must be done by engineers who have hands-on, operational-at-sea experience. The Navy, recognizing this shortfall, has for a number of years utilized the techniques of Design Work Study Technology to overcome this and requires contractors who design manned systems and spaces to be trained and experienced in Design Work Study techniques. Design Work Study can be defined as a methodical approach to the design of systems, both technical and physical, which accommodates and conserves man's effort by considering him the single most important component (and variable) in the system. From a historical perspective, both human factors engineering and Design Work Study Technology had its origins in the work undertaken by Taylor in the late nineteenth century in developing scientific management principles and job design, and subsequent studies addressing time and motion conducted by the Gilbreths in the early part of this century. The concepts and techniques of Design Work Study until fairly recently were directed almost exclusively to the design of physical space configurations. Its application to the design of the technical system was not vigorously pursued until very recently. The advent of the integrated combat system and the introduction of a third system variable, namely that of software, to the always tenuous man-machine equation are forcing combat systems designers to seek a commonality of techniques in the design of both hardware and software systems, and the design of the shipboard space.

The Design Work Study techniques interject the human operator into the design process at every stage of the design. In order of application they are:

- Functional Analysis

- Functional Flow Diagrams (FFDs)

- Operational Sequence Diagrams (OSDs)

Functional Analvsis

Essential to the development of any system is an accurate analysis of what, in terms of functions, is required to be accomplished. In its purest sense it addresses the "what" of the system, not the "how." Functional analysis is a widely employed systems engineering technique which examines the hierarchy of functions required to be accomplished in the order of their happening. In ship system design, functional analysis *is* directed towards a specialized application in that it examines the total ship system input/output relationships within a priority structured environment and is event based, representing, for instance, the sequence of actions required to transpire in the prosecution of an engagement. This slide (see Slide 2) is *a* partial example which demonstrates the technique. Functional analysis is the beginning of combat system design and its conduct affects the validity of all other design products to which it inputs. Its principal benefits to combat system design are to:

- Define candidates for modular software in terms of functions

- Define candidate operator functions

- Provide a structured basis for design traceability

Functional Flow Diagrams

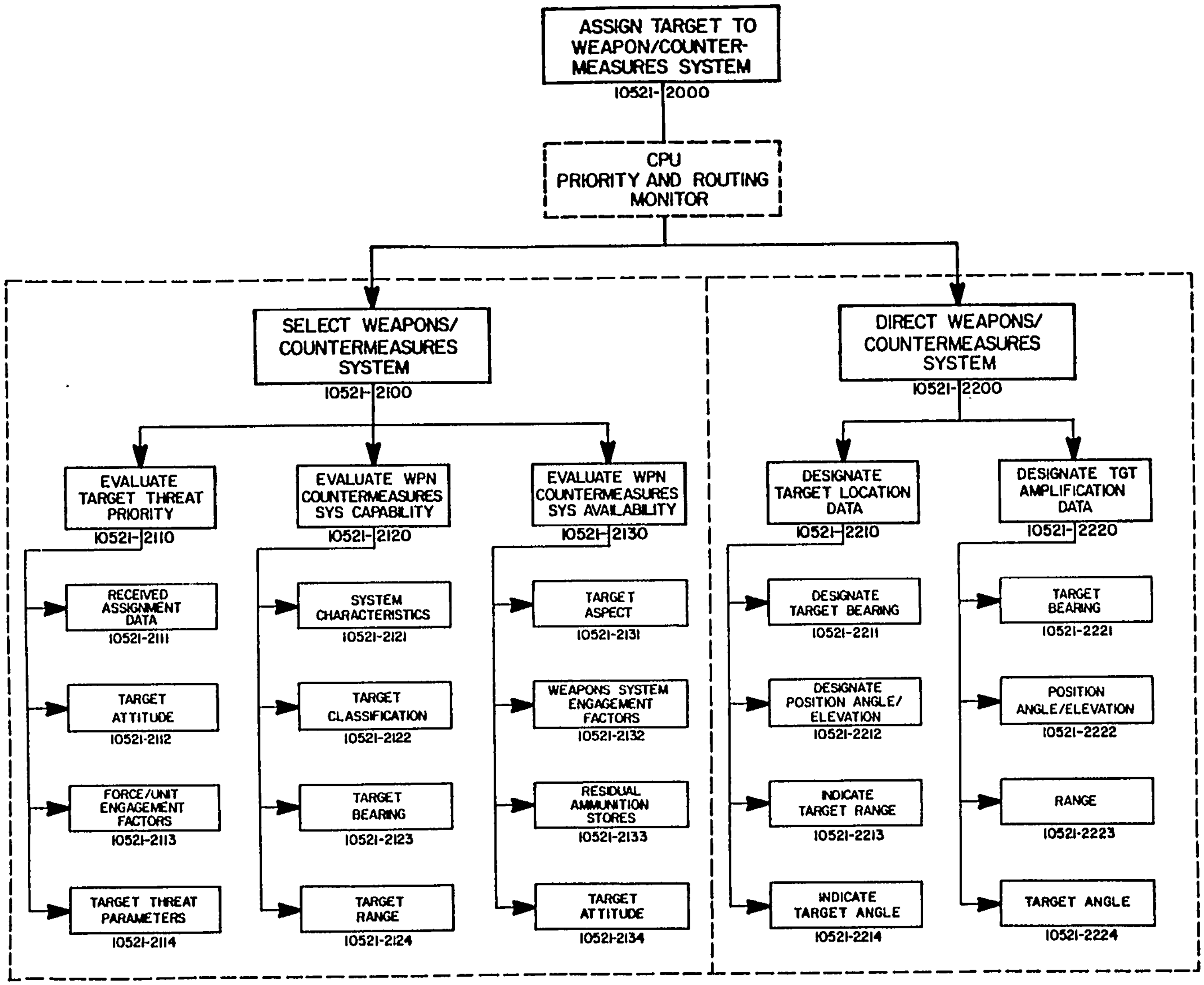
Functional Flow Diagrams (FFDs) are an onward refinement of functional analysis, serving to allocate the functions identified by functional analysis to operators, candidate equipments, and candidate software. FFDs meld equipment, operators, and supporting software into functional equipment/software systems modules and reflect the actions and interaction of men, equipment, and software. This slide (see Slide 3) shows a partial example of FFDs. FFDs interject the dynamics of system operation into the design process, levying on the systems designer a requirement to be consciously aware of the system's ultimate environment early in the design development process. This specialized application of FFDs to combat system design is probably unique in that the following basic assumptions apply to FFD development.

- FFDs shall reflect the operation of systems in the maximum tactical environment presuming simultaneous operation of all systems.

- All systems are operational with no constraints or parameters applied (i.e., no casualties).

- FFDs are event based and do not reflect the stresses and strains of an applied scenario; that is, FFDs describe multiple threats (air, surface, subsurface) but <u>not</u> multiple targets within a threat category.

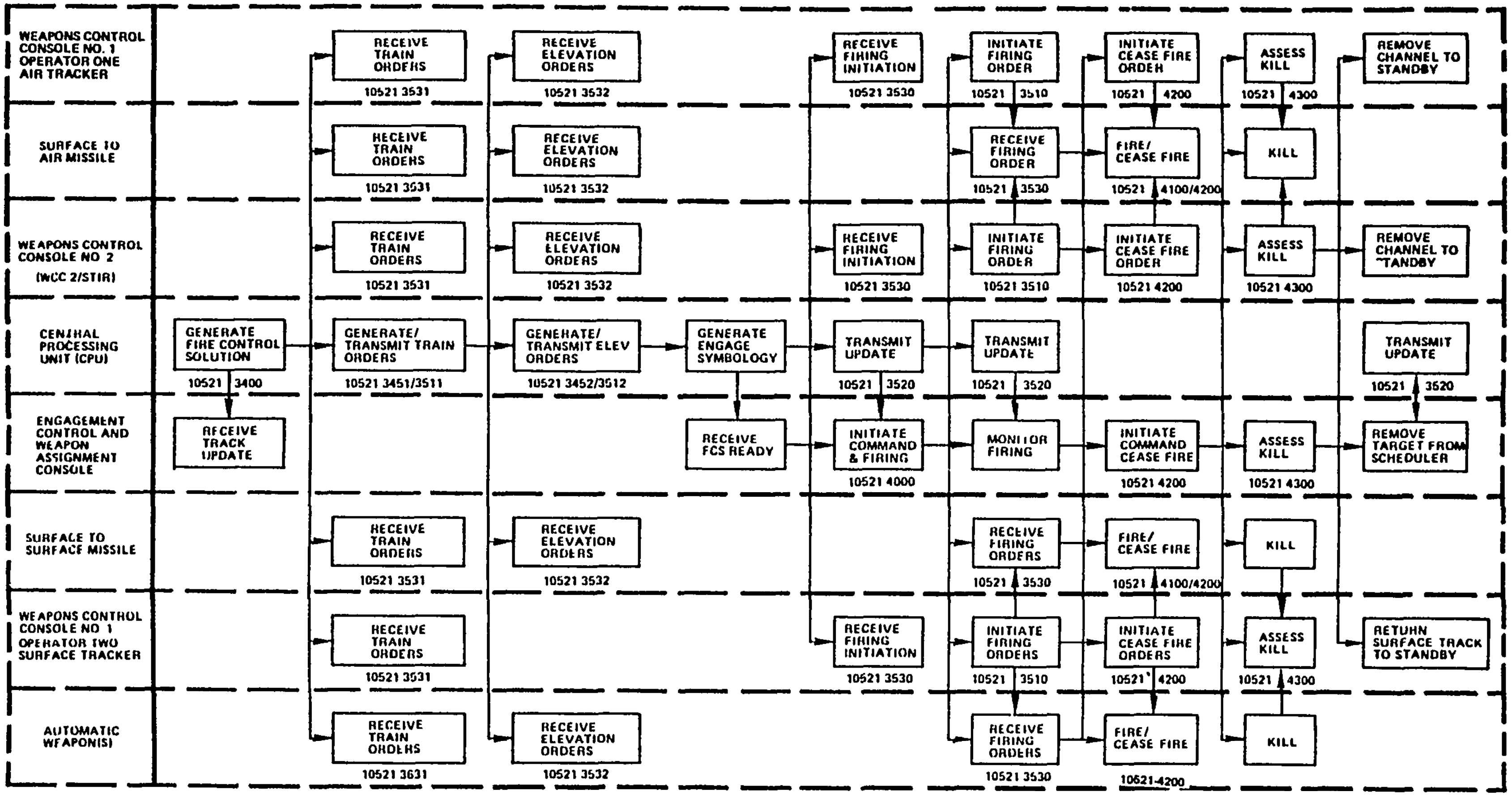
FFDs are cast deliberately and exercised within the parameters of the above assumptions so as to establish optimums with respect to input/output relationships and to establish a "worst case" baseline for trade-up/trade-down alteratives. Having established optimums in terms of input/output relationships in this manner (multiple threat but not multiple target within a threat category)



STAGE IDENTIFICATION DIAGRAM - FUNCTIONAL ANALYSIS RESULTS

SLIDE #2

ANTI-AIR AND SURFACE WARFARE SYSTEM/WEAPON CONTROL/COMMAND FIRING MODULE



REPRESENTATIVE FUNCTIONAL FLOW DIAGRAM (FFD)

SLIDE #3

accommodating the stresses of a scenario reflecting the actual operational environment in which multiple targets are present is merely a matter of providing system redundancies to support the optimums identified through FFD exercise. FFDs provide the basis for subsequent design products. These include:

- Development of Operational Sequence Diagrams and subsequent evaluations of system capability to meet required operational capability.

- Development of Contract Guidance Arrangement Plans and Drawings (room arrangements)

- Development of detailed systems drawing plans and technical documentation

- Development of user technical and operator manuals

- Development of system test requirements

- Development of preliminary software support requirements

Operational Sequence Diagram

Operational Sequence Diagrams (OSDs) afford a means of evaluating the designed system against valid operational criteria. Whereas FFDs were constrained to reflect no casualty or stress condition, OSDs are not so constrained. OSDs are exercised against a Tactical Operational Scenario reflecting real-life, multiple-target situations within the maximum tactical environment. A partial example is provided in this slide (see Slide 4). OSDs reflect the actions and interactions of men, equipment, and software in the actual combat environment. OSDs are a test of the designed system to meet its operational requirements. OSDs are developed to a level of detail to highlight the action(s) and interaction(s) of an operator with his equipment and the system's response to his actions, that is, the action of an operator depressing a named action entry button on his console and the system software or hardware, or both, response(s) in terms of a data readout, dial change, or automatic visual display. OSDs allow a refinement of designed products generated by the exercise of FFDs and are the basis for the detail design. OSDs help:

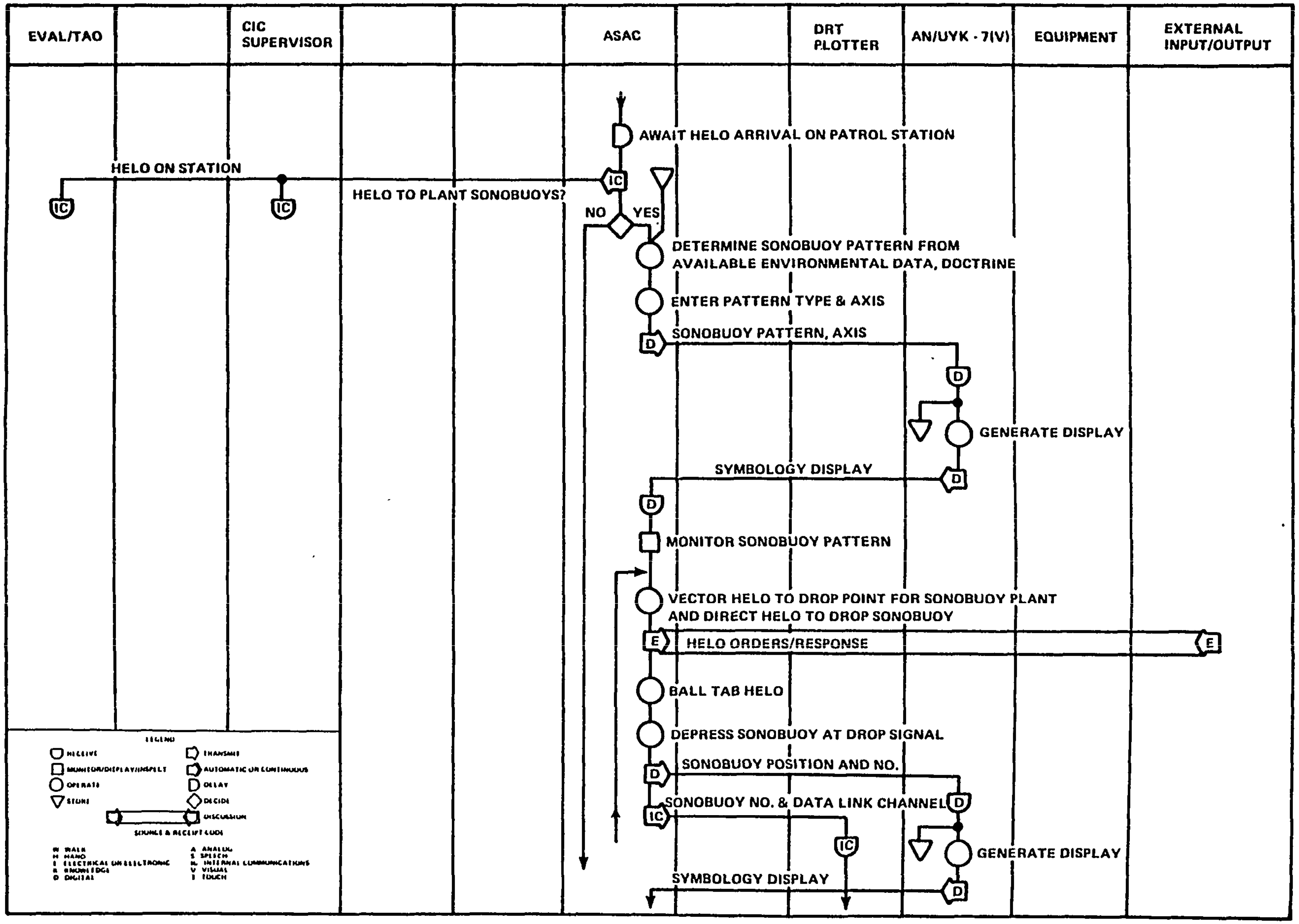
- Provide a means for validation of the developed design in terms of its operational environment.

- Constitute a basis for developing the software operational specification by affording nearly direct conversion of OSDs to computer program logic format.

- Define requisite men, equipment, and software relationships which input into the development of space configurations (physical design).

- Identify system incompatibilities.

- Provide a programmable base by which the systems can be exercised (war gamed) on a computer to facilitate detail design and evaluate system performance.



REPRESENTATIVE OPERATIONAL SEQUENCE DIAGRAM, DESTROYER TYPE SHIP, CONDUCT, CONTROL, COORDINATE ASW OPERATIONS

- Input to the development of ship system test and operational manuals.

- Provide a precise and detailed definition of the man-machine-software interface as a basis for system integration.

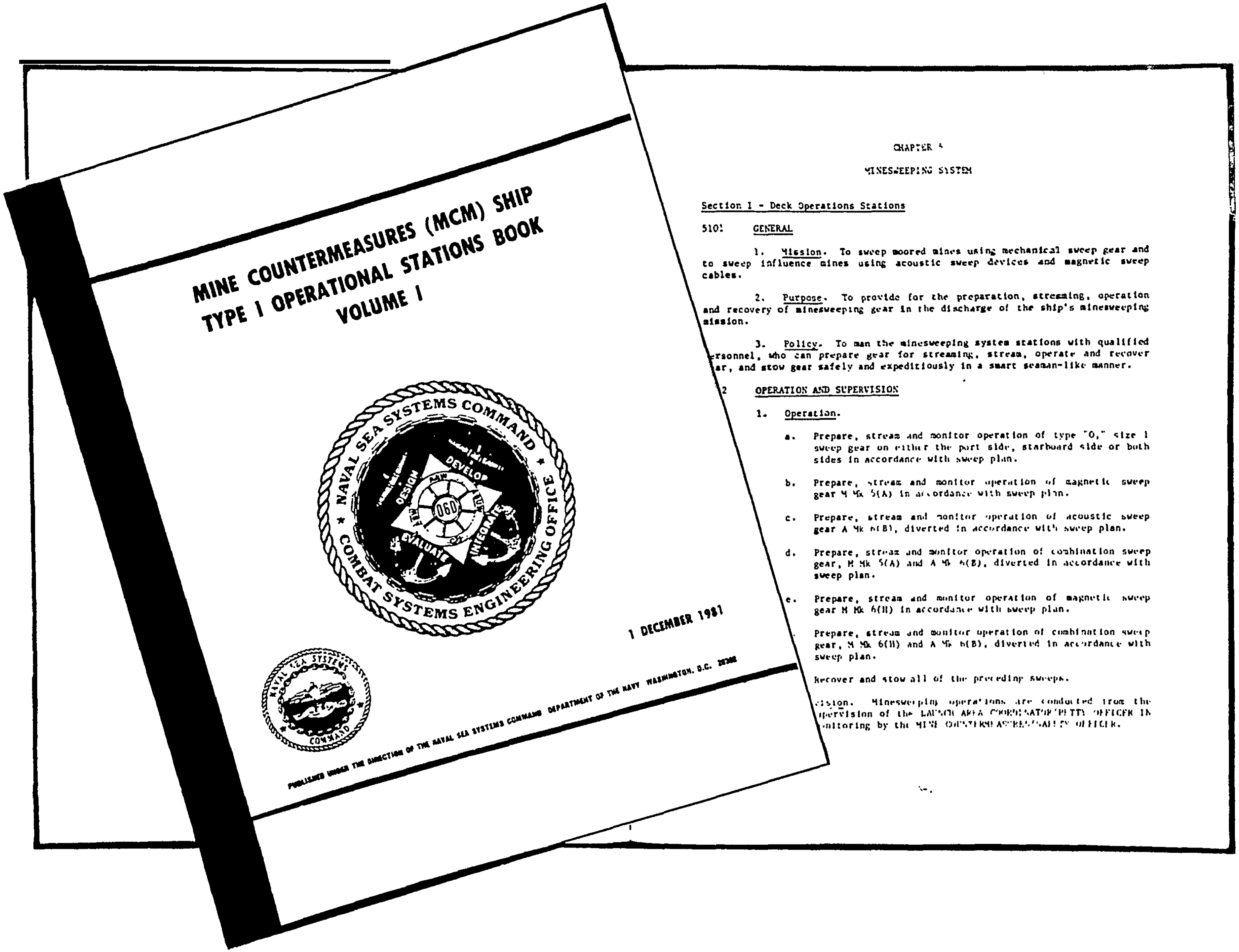
Granted, the idealized application of all of the above techniques seldom, if in fact ever, occurs. It is, therefore, imperative that the techniques be directed toward validation in place of definition of systems. The cause-and-effect nature of technology and off-the-shelf hardware should not serve to constrain or tailor the techniques themselves, but rather their application should provide a viable means for the generation of trade-up/trade-down alternatives within the parameters imposed, based on acceptable risk. The concurrent design of both hardware and software and the adaptability of software design to-the particular techniques afford the designer many software alternatives to correct the functional inconsistencies generated by a dictated hardware suite.

IV. OPERATIONAL STATIONS BOOK

Of the many benefits of FFD and OSD exercise, the most important outputs from a human factors engineering and. modeling standpoint are the development of the Operational Stations Book (see Slide 5) and the space configuration design. As we stated previously, OSDs define not only the tasks which the system (equipment/software) must perform, but more importantly, they are a precise statement of the tasks which an operator must accomplish in support of the overall system. Once OSDs are completed, it is a simple matter to extract the columnar data and translate it in work process flow chart form for inclusion in the Operational Stations Book. OSDs are the vechicle by which Task Analysis and Task Design are accomplished and the Operational Stations Book is the document which describes in narrative and work process flow chart form each individual operator's tasks in support of the system. This slide (see Slide 6) is an example of a Work Process Flow Chart.

v. SPACE CONFIGURATION DESIGN

Ship design is directed toward the design not only of the weapons system itself, but of the ships system as well. The basic Design Work Study techniques serve to input not only the design of the technical system but to prescribe also its sitting within the platform and the degree of closeness which can be afforded its operators. This aspect of the system design, that of the physical design of the operating spaces, in many cases overshadows that of the actual technical design in terms of economical utilization of space and manpower. Recent estimates place the life cycle cost of putting one man aboard ship at approximately $1.5 million. In addition, there is an additional 5,000 pounds in life support systems and materials. Any technical system which fosters a proliferation of operators is extremely expensive from a life cycle cost effectiveness viewpoint as well as from its weight and moment aspects. For this reason, system design must include not only the design of the technical system, but the detail design of the shipboard operational space as well, with the view of eliminating or combining functional operating positions and conservation of human effort. This slide (see Slide 7) shows the relationship of the system design using the Design Work Study Techniques to the Physical Design of the shipboard operational space.



MINE COUNTERMEASURES (MCM) SHIP
TYPE I OPERATIONAL STATIONS BOOK
VOLUME I

1 DECEMBER 1981

PUBLISHED UNDER THE DIRECTION OF THE NAVAL SEA SYSTEMS COMMAND DEPARTMENT OF THE NAVY WASHINGTON, D.C.

CHAPTER 5

MINESWEEPING SYSTEM

Section I - Deck Operations Stations

5101 GENERAL

1. Mission. To sweep moored mines using mechanical sweep gear and to sweep influence mines using acoustic sweep devices and magnetic sweep cables.

2. Purpose. To provide for the preparation, streaming, operation and recovery of minesweeping gear in the discharge of the ship's minesweeping mission.

3. Policy. To man the minesweeping system stations with qualified ersonnel, who can prepare gear for streaming, stream, operate and recover ar, and stow gear safely and expeditiously in a smart seaman-like manner.

2 OPERATION AND SUPERVISION

1. Operation.

a. Prepare, stream and monitor operation of type "O," size 1 sweep gear on either the port side, starboard side or both sides in accordance with sweep plan.

b. Prepare, stream and monitor operation of magnetic sweep gear M Mk 5(A) in accordance with sweep plan.

c. Prepare, stream and monitor operation of acoustic sweep gear A Mk 6(B), diverted in accordance with sweep plan.

d. Prepare, stream and monitor operation of combination sweep gear, M Mk 5(A) and A Mk 6(B), diverted in accordance with sweep plan.

e. Prepare, stream and monitor operation of magnetic sweep gear M Mk 6(H) in accordance with sweep plan.

Prepare, stream and monitor operation of combination sweep gear, M Mk 6(H) and A Mk 6(B), diverted in accordance with sweep plan.

Recover and stow all of the preceding sweeps.

vision. Minesweeping operations are conducted from the upervision of the LAUNCH AREA COORDINATOR/PETTY OFFICER IN onitoring by the MINE COUNTERMEASURES/SAFETY OFFICER.

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SLIDE #5

WORK PROCESS FLOW CHART

ASW AIR CONTROLLER Specific Task Accomplishment

1 Receive order from EVALUATOR to take control of helo.

1 Search PPI for helo on launch.

2/1 Establish communications with helo by voice radio.

2 Check for patrol station being entered.

2 If patrol station not entered, enter same by:

a Ball-tab patrol station position

b Depress REF POINT

a Observe PPI for reference point symbol

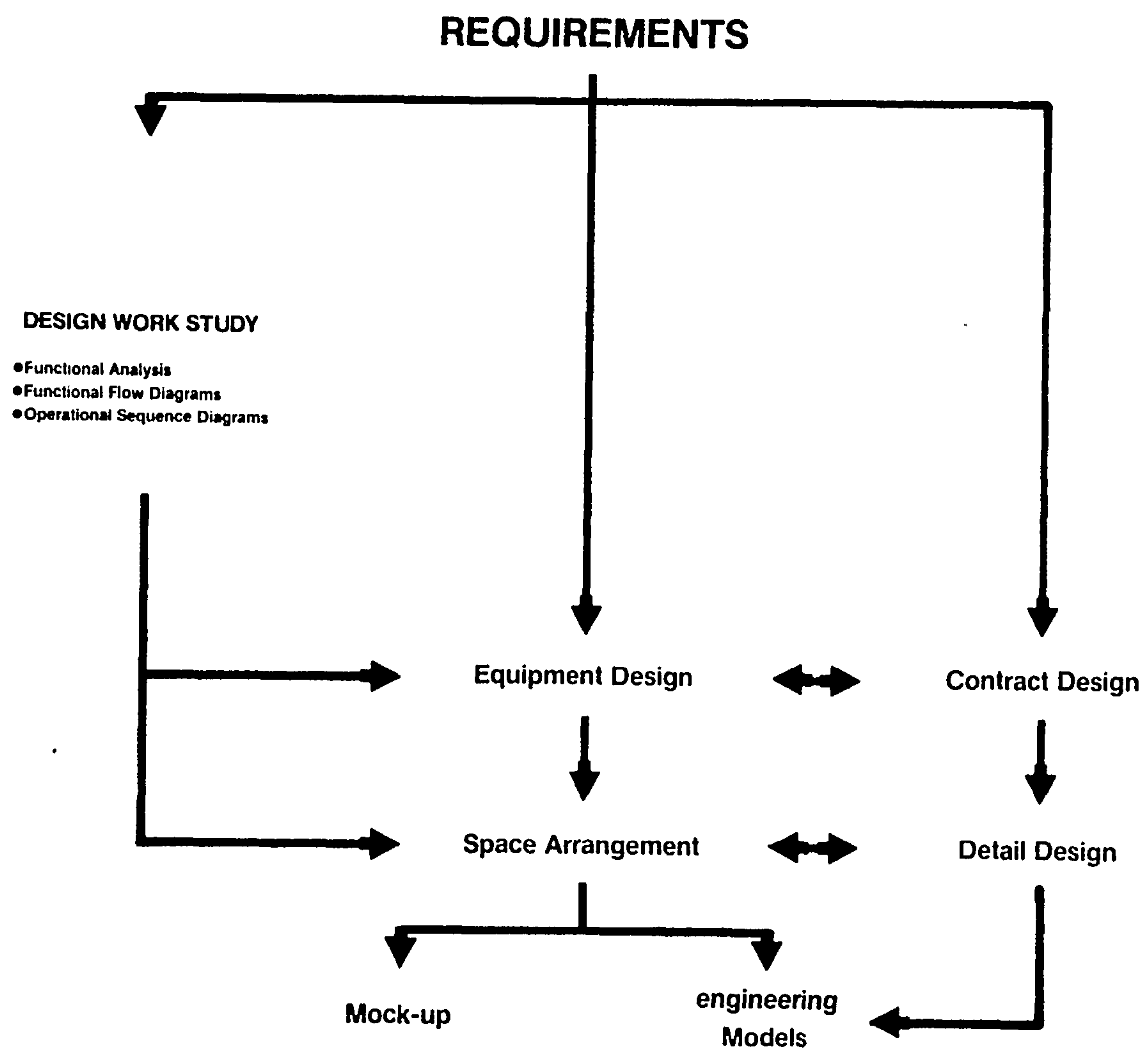
3/3 Vector ASW helo to patrol station.

3 Determine if ASW helo parameters in system.

4 Enter ASW helo parameters (number and type sonobuoy, number and type weapon) by keyset if required.

SLIDE #6

RELATIONSHIP OF SYSTEM DESIGN AND PHYSICAL DESIGN



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SLIDE #7

The operational effectiveness of ship systems depends largely on the inter- and intraspace arrangement of the man/equipment subsystems. Subsequent to FFD and OSD exercise, the design agent analyzes these arrangements to determine what critical adjacencies, operator-to-operator, operator-to-equipment and equipment-to-equipment, must exist in order for the system to perform effectively. These are examined in terms of closeness and reason as follows:

Closeness Value	Code
- Absolute closeness	(A)
- Digital	(D)
- Electrical	(El
- Interior Communications	(I)
- Necessary Closeness	(N)

Reason	Code
- Hands-on Control	(1)
- Overview/Coordination	(2)
- Supervision/Direction	(3)
- System Requirement	(4)
- Control/Utilization	(5)

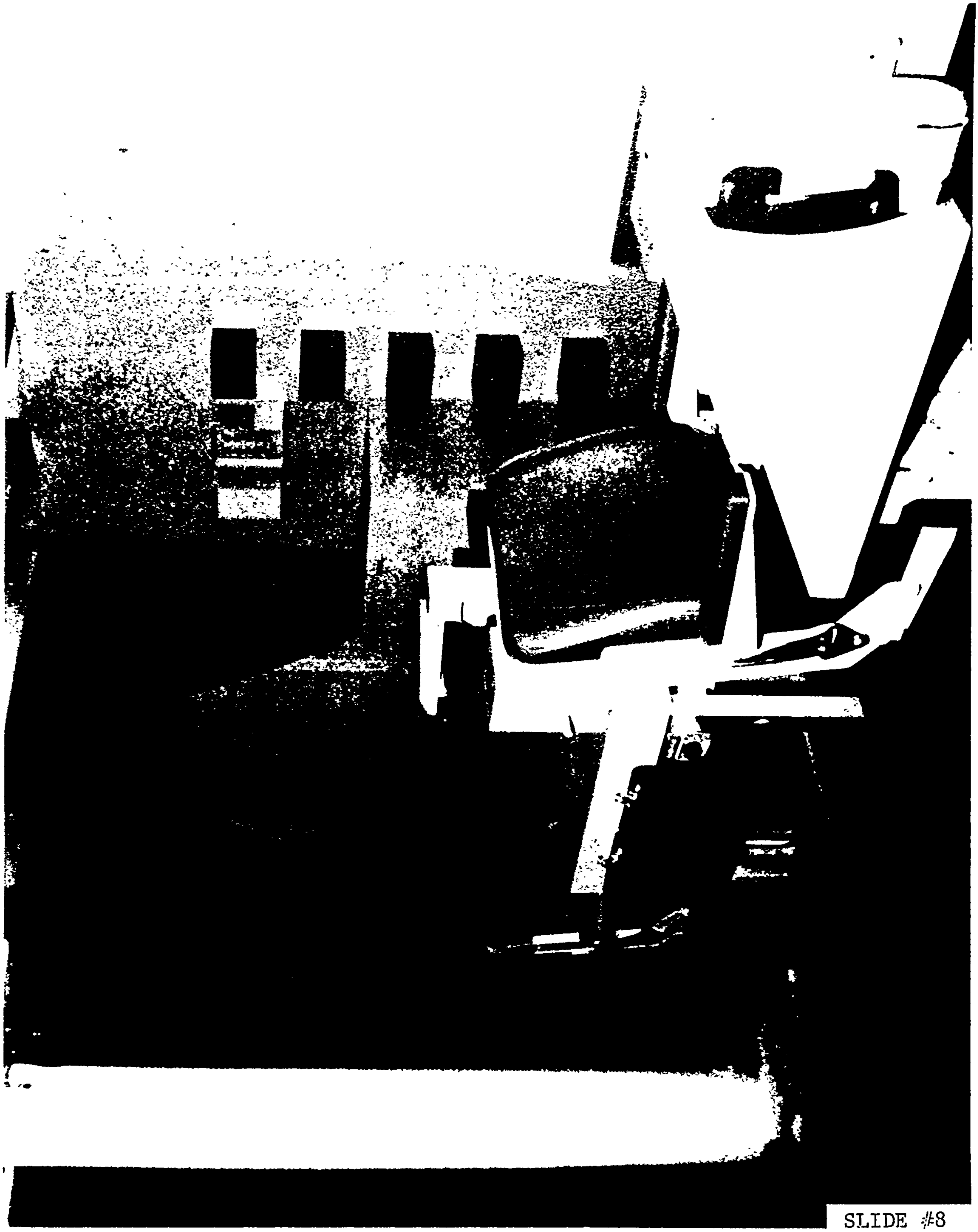
Using correlation matrix techniques and coding as shown, the system analyst determines what precise relationships exist between each operator and every other operator, each operator and his equipment, and each piece of equipment and all other equipment.

Having established these relationships, it becomes a simple matter to develop spatial relationship diagrams depicting graphically the requisite adjacencies. These diagrams are then laid to a shipboard space and become the basis for the space configuration design and the construction of physical 3-D models and/or mock-ups.

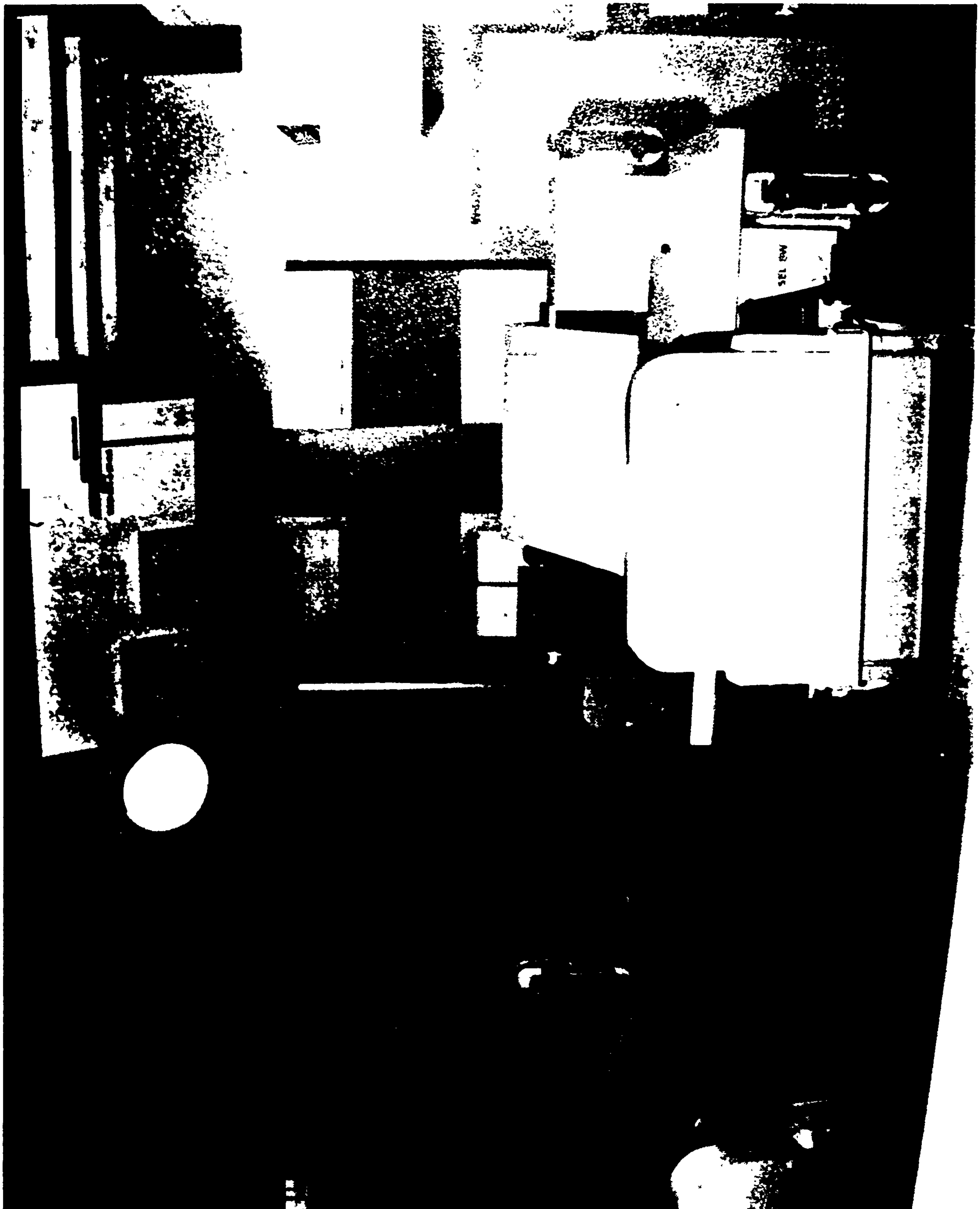
Physical models are beginning to emerge not only as an effective design and communication tool for detail design of shipboard operational space, but as an aid for human factors engineering and verification of the conceptual models. Without the model, it is difficult to study human factor considerations such as headroom, equipment access, traffic patterns, lighting, and other features that tend to reduce fatigue and stress factors.

Combat Information Center (CIC)

A full scale mock-up was constructed of the CIC (see Slides 8 and 9). The primary purpose of these mock-ups was to test the arrangement in terms of the suitability and operability by its human operators. It also validated the



SLIDE #8



SLIDE #9

results of the Design Work Study. The secondary purpose of the mock-up is to use it for training cadre crews in the last stages of MCM construction. In its training role, the mock-up will contain actual equipment.

Deck Arrangement

A scale model of the MCM Deck (see Slide 10) was constructed to test not only the arrangement of equipment, but to test the feasibility of the equipment to handle the mine sweeping/mine hunting mission in terms of deploying and recovering the mine neutralization vehicle and mine sweeping gear (see Slide 11).* It is a semi-working model in that the cranes operate and the winches turn and can demonstrate some of the equipment functions. Numerous human engineering and engineering design decisions were made based on this model at a considerable cost savings to the government. This slide, (see Slide 12) looking to port from aft, shows the two articulated cranes, the mine neutralization vehicle in its cradle (starboard side up and forward), and the stern rolling shock (centerline on the stem), all of new and revolutionary design.

Machinery Arrangements

Arrangement studies are an extension of contract design, only in a more detailed manner. These studies are usually prepared so that all of the design sections will be able to work simultaneously and independently for producing the optimum machinery space arrangement. These studies should also coordinate the requirements of operation, maintenance, and safety.

One of the early models constructed during detail design of the MCM was an arrangement study model (see Slide 13).* This model is a 3-D composite mechanical engineering drawing. Location was verified for machinery and equipment, dimensions were set for structures, space was allocated for routing of Pipe, electrical panels, wireways, instrument lines, and HVAC. Access, removal space, and handling areas were outlined and verified. This model saved countless hours of space rearrangements as many problems were resolved prior to the start of detail design. The model is still being used as a planning and construction aid.

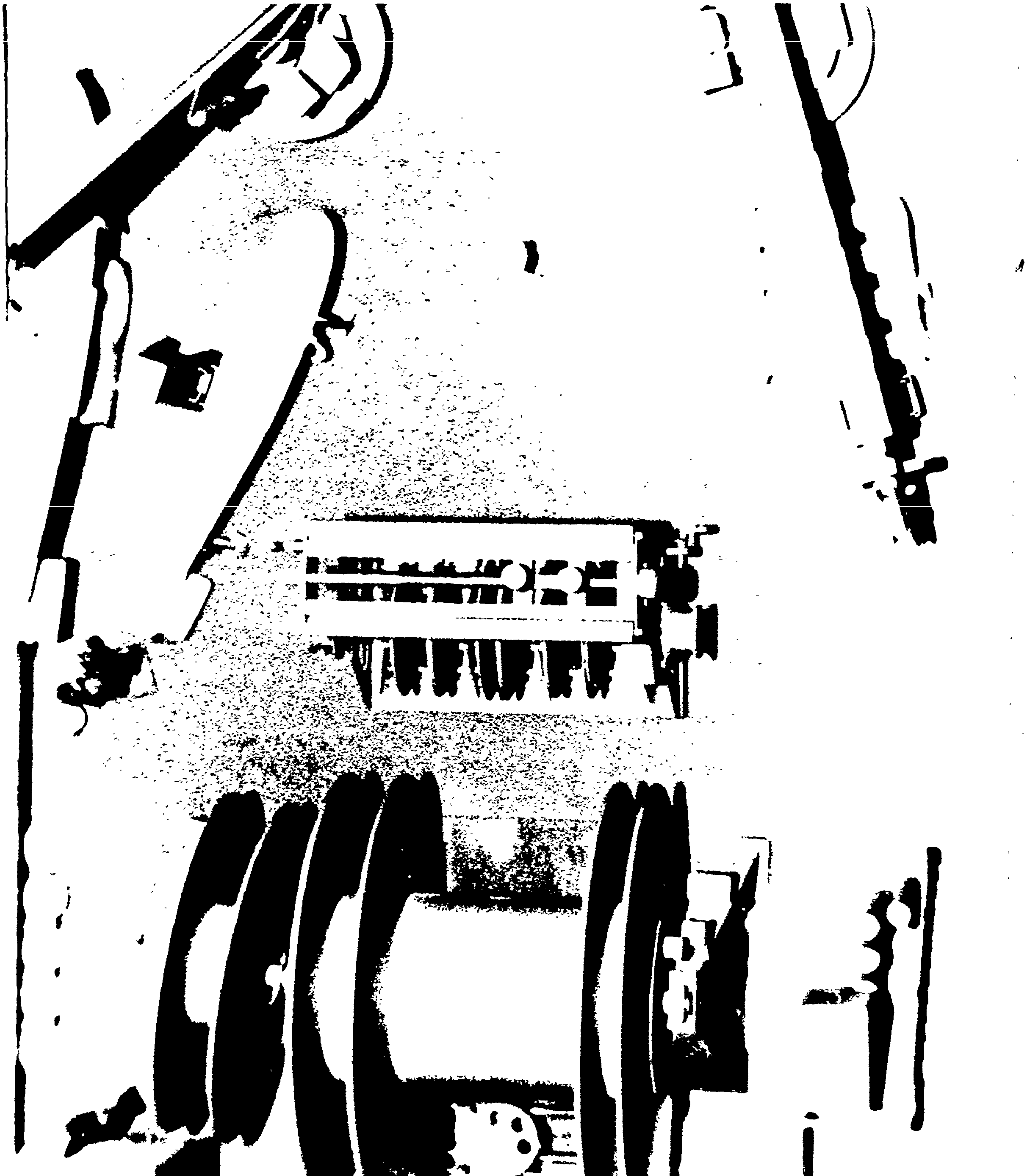
Distributive System Studies

Perhaps one of the most effective, but under-utilized, functions of models is for human factor studies. If seamen designed ships, I am sure the ship would be easier to operate and maintain. However, since that is not the case, the models can substitute for some of that experience. The model communicates to the systems and design engineers the human factor problems and can help the designer accommodate human beings and their operating requirements, rather than forcing man to adapt to the system.

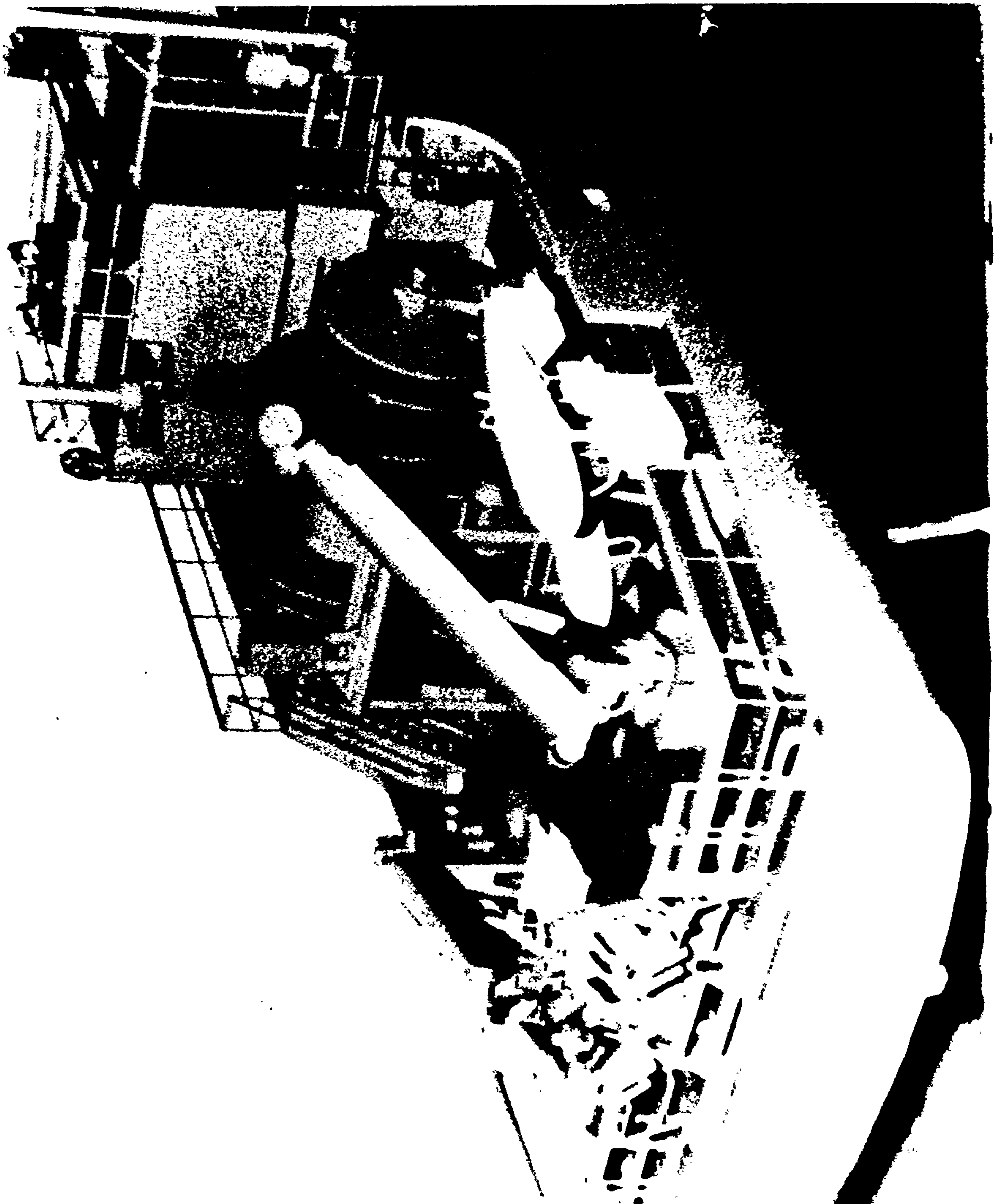
The quality of any machinery space design is put to test by the operators. If they have convenient access to points of operation, inspection, and handling, the propulsion plant has been well designed from their standpoint. Access is the most important feature of ship design. Good machinery arrangement with access minimizes the cost of maintenance.

Scale models of the MCM machinery rooms are being used for design and space allocation study from a maintenance and human factors aspect.

*Note: Slides #11 & #13 not included.



SLIDE #10



SLIDE #12

The slide (Slide 14) is one of the MMR port looking outboards showing the accessibility around the engine. It also shows the D.C. propulsion motor controller, and space allocated for the camshaft removal.

This slide (Slide 15) is of the starboard side of the MMR showing sea water piping and accessibility to valves.

This slide (Slide 16) is the AMR looking aft and outboard showing the gas turbine magnetic mine sweep generator and exhaust ducting. Again, adequacy of space for normal and abnormal operation were being verified.

The model played a key role in locating the degaussing piping. This slide (Slide 17) is of the AMR looking inboard and shows some of the degaussing piping, the distillers, and reserved space for pulling the bundles. Space is also being reserved for the Switchboard Ship Service.

This slide (Slide 18) of the AMR looking outboard shows the convenience of the phone booth and space being reserved for Control Panels.

This slide (Slide 19) of the port side of the AMR looking forward shows the area around the reduction gear and stop check valve.

Attention must be given to the interface between man and equipment. Equipment arrangement must ensure efficient and safe operation. Consideration must be given to the display of information, and the equipment must be designed and located for maintainability. These 3-D models made sure these criteria were met and permitted the best possible arrangement of machinery and piping systems, and the best location of HVAC, wireways, valves, switchboards, and panels, lighting fixtures, and openings.

VI. PERSONNEL SUBSYSTEM

The third area of responsibility is the personnel subsystem. The personnel subsystem implies attention to equipment design and to the personnel that must operate and maintain the equipment. Personnel subsystem activities generally follow and are based upon the results of the human performance requirements and space configuration design. During this phase, manpower requirements are determined for each job, training aids and devices are developed, and checklists are prepared for system operation.

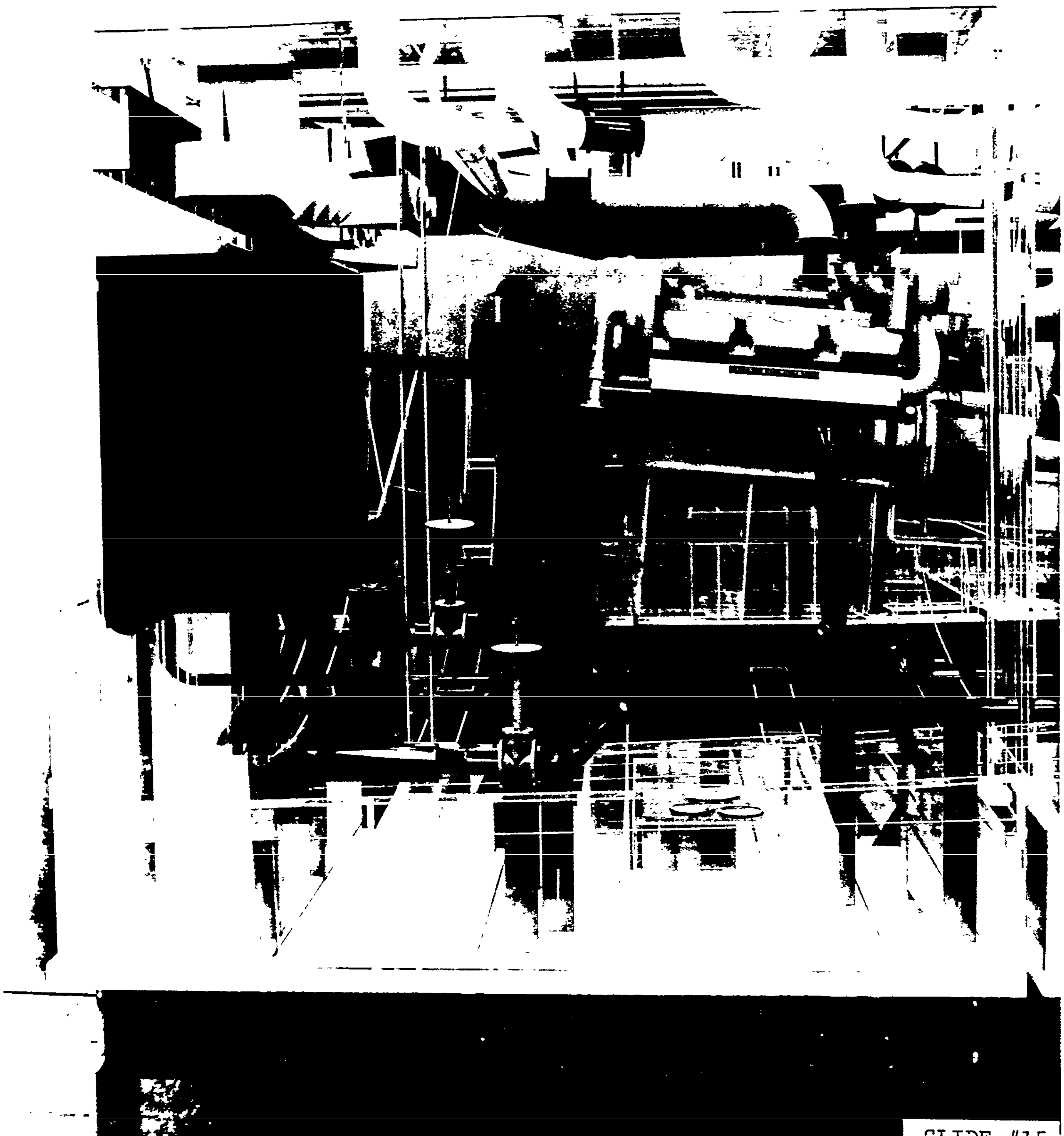
During the function identification, only gross system functions are identified, not the personnel or equipment that will accomplish the functions.

From a personal subsystem standpoint, function allocation is the process of deciding what man will do in the operation, maintenance, and control of the system. The objective is to select the design approach most likely to satisfy the functional requirements.

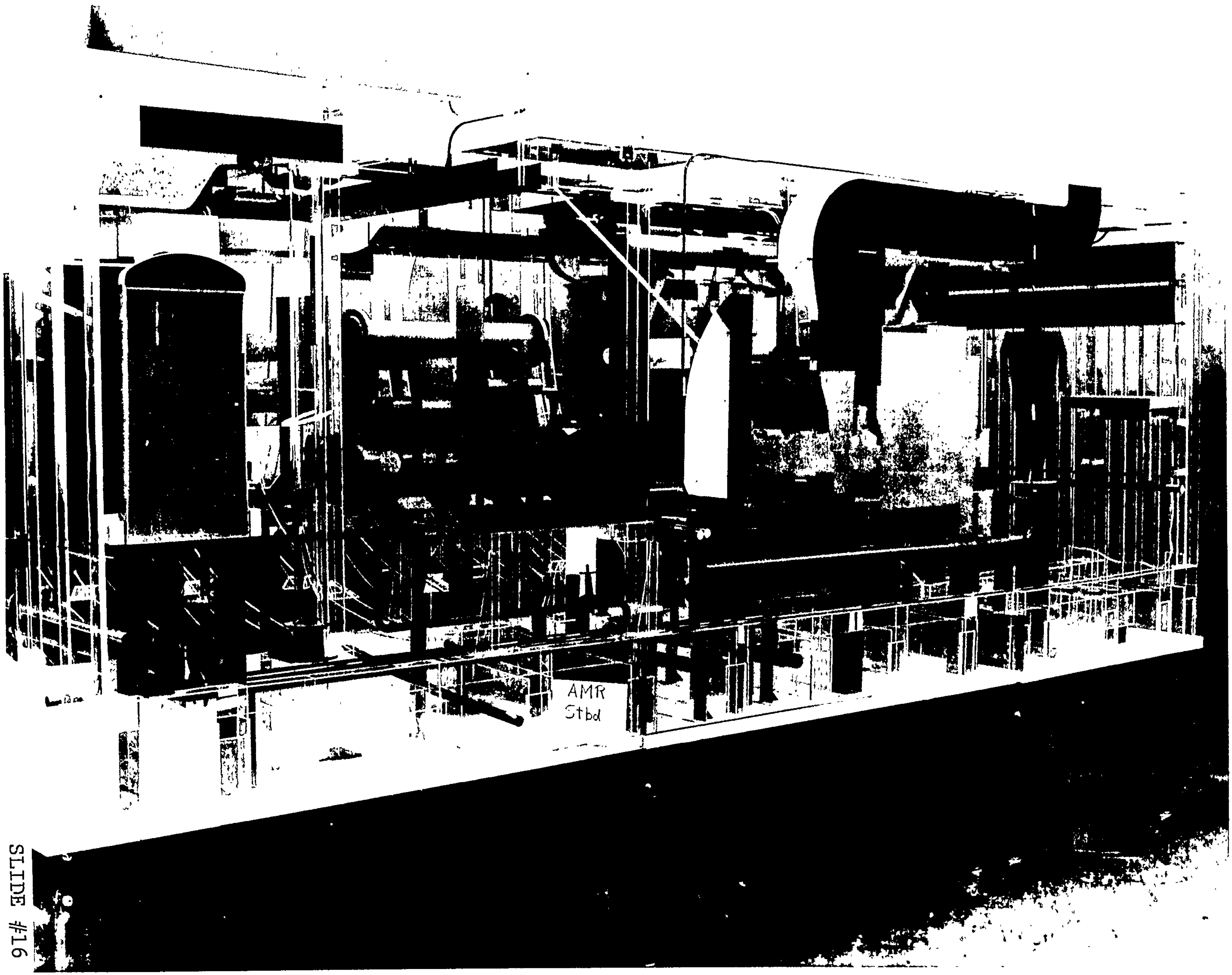
VII. SUMMARY

Human factors engineering, in method and concept, has as its principal concern the design of efficient and safe man-machine systems. The Design Work Study concept and physical models are powerful tools to support this concern. You don't have to be a human factors expert to design a safe ship; all it takes is the application of common sense and practicality.

SLIDE #14



SLIDE #15



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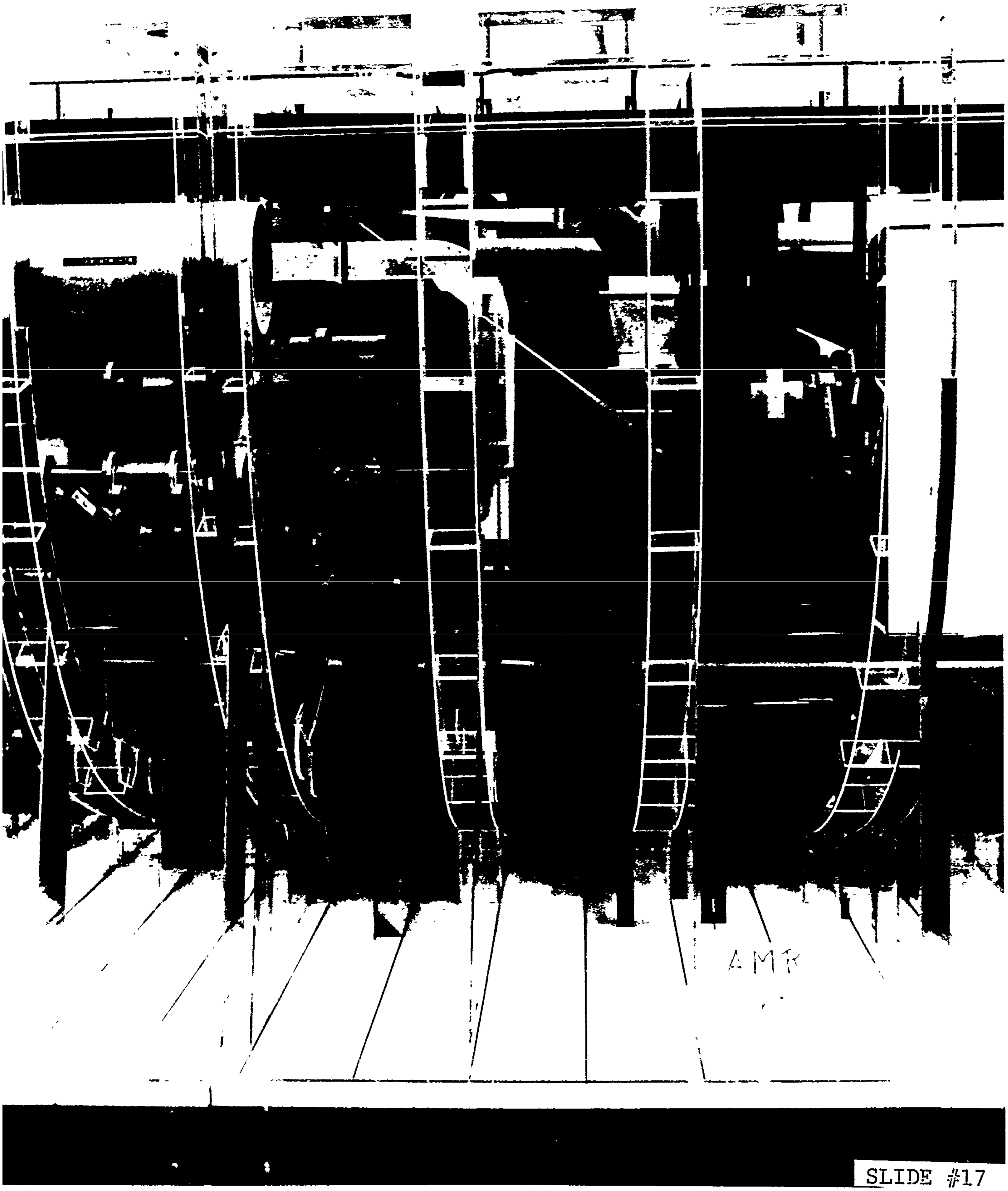

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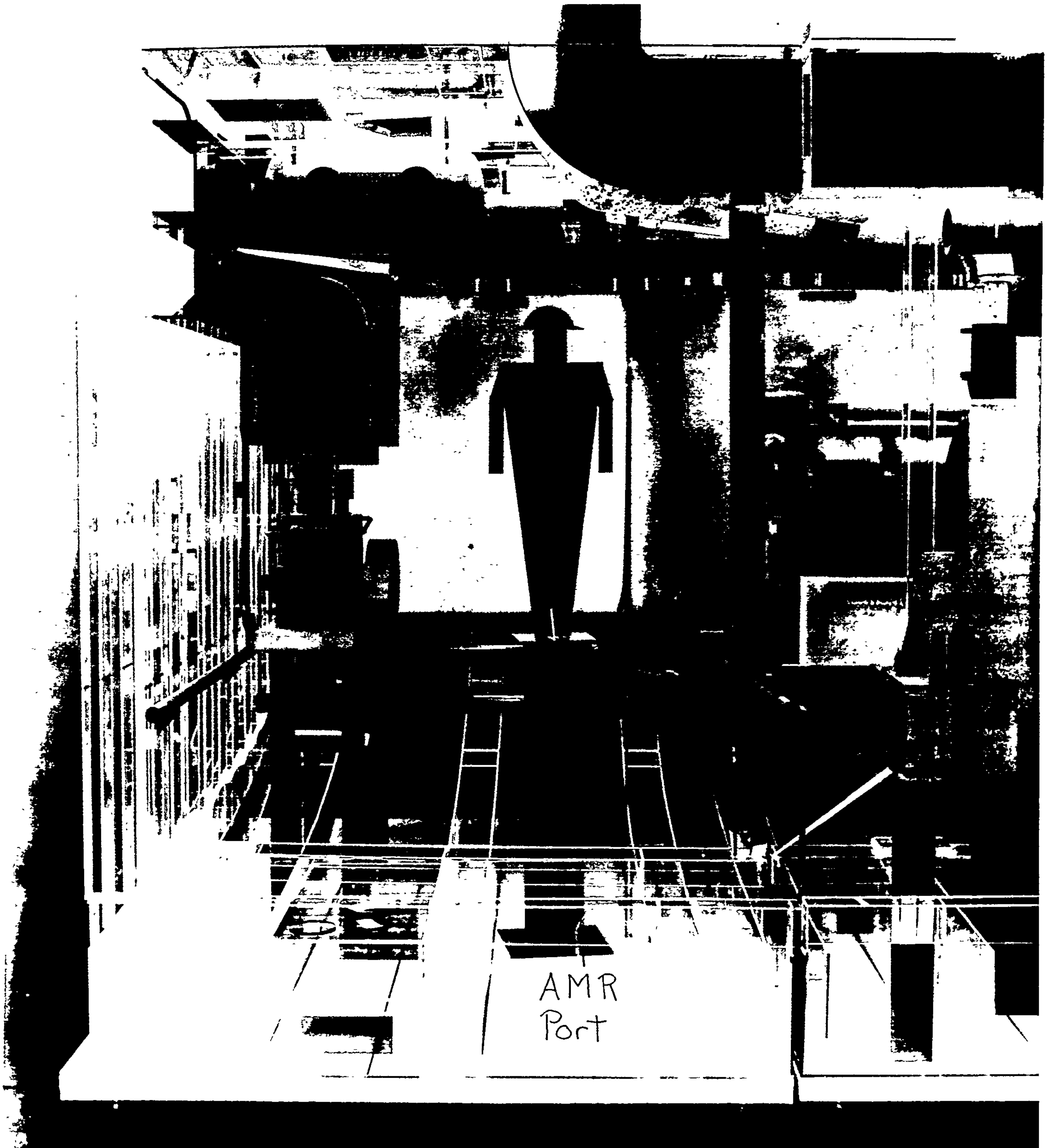
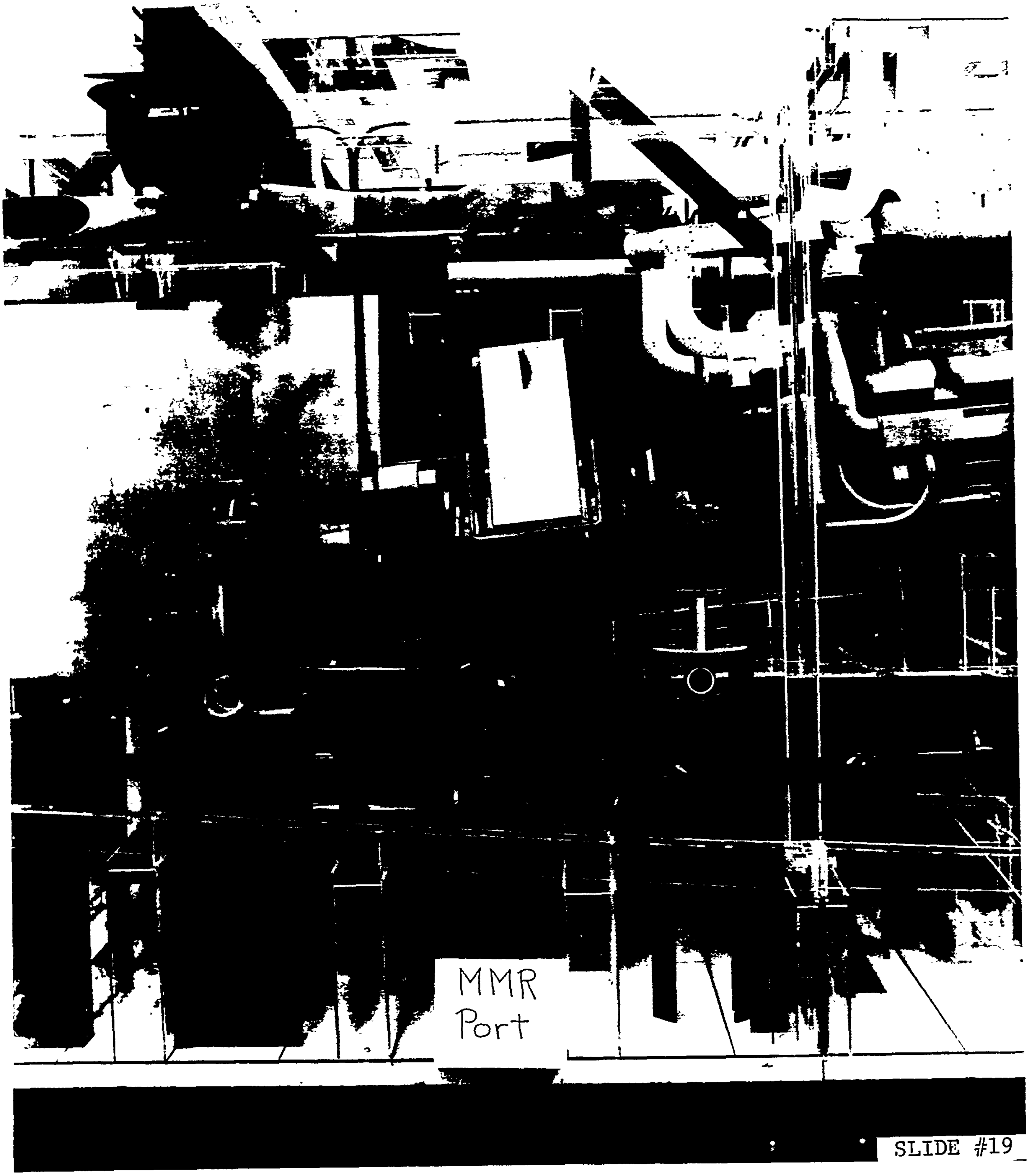


SLIDE #18



SLIDE #19

The value of physical models of complex machinery spaces and other common areas was amply demonstrated. The designers found them especially useful for the presentation of equipment and distributive systems in 3-D and in the working relationship with surrounding equipment and particularly useful in developing design improvements and verifying maintenance requirements.

To quote from Joe Castle's STAR Symposium paper again:

"It is anticipated that the Navy and Industry will be working closely together to develop and incorporate man-machine technology into design of jobs equipment and systems for the Surface Navy. These efforts will require:

- Increased Human Factors Engineering resources and feedback in ship and ship system acquisition.

- More man-machine analysis during early system development.

- Use of models, mock-ups, and simulators in developing and resolving operator and maintainer interfaces.

- Improved design standards, shipbuilding specifications, contract incentives and monitoring procedures in terms of human factors engineering."

BRITSHIPS 2 - A COMPUTER AIDED DESIGN AND PRODUCTION SYSTEM USING COMPUTER GRAPHICS

D. R. Patterson
British Ship Research Association
Tyne and Wear, England

After an Engineering apprenticeship,Mr. Patterson entered the University of Durham to study Naval Architecture. After graduation, he spent three years as a William Froude Scholar doing research into wave resistance of ships. Part of the post-graduate period was spent in the Ship Division of the National Physical Laboratory. Mr. Patterson gained practical shipyard experience in the Ship Design Office of Hawthorn Leslie (Shipbuilders), Hebburn on Tyne.

Mr. Patterson joined BSRA in 1965 and for a period of ten years he was head of the Hydrodynamics Section. In this capacity he was responsible for reseach into resistance and propulsion, seakeeping, and the steering manoeuvering and stopping of ships. In 1975 he was concerned with the development of the applications system for Computer Aided Ship Design. He is at present Senior Manager responsible for the Technical Services Department within BSRA and is responsible for the contract work undertaken by that Organization. He is a Member of the Royal Institution of Naval Architects.

ABSTRACT

BRITSHIPS is the generic title for a computer system built from related ship design/production softrware created by the British Ship Research Association (BSRA). The integrated system has been the subject of continuous development since it first went into use in the late 1960's, and won a Queen's Award to Industry for technological innovation in 1974. BSRA is the central research and development agency for the British shipbuilding industry. BRITSHIPS has been developed in close consultation with the industry and is a reflection of the practical needs of the shipbuilders. The system is constantly updated in line with advances in design and production technology, advances in computing methods, and the developing requirements of the shipbuilding industry.

The latest version, known as BRITSHIPS and sponsored by British Shipbuilders, supports the shipbuilding process from the design of the hull form through design analysis, steelwork design, production definition of the hull form, lofting, piping, to assembly drawings and sketches, and production and materials requisition information.

This paper describes the structure and organization of the system, and the facilities it offers.

ABOUT BSRA

The British Ship Research Association (BSRA) is one of the largest research organisations in the world devoted to marine technology. Its staff of some 200 includes naval architects, marine engineers, mechanical engineers, physicists, chemists, mathematicians, computer specialists and economists all with specialist knowledge of the marine application of their subject.

Since its foundation in 1944, BSRA has conducted a planned programme of research to advance ship and shipbuilding technology. The knowledge and experience gained embraces virtually every aspect of marine technology: hydrodynamics, structures, engineering systems, automation, shipbuilding technology, vibration and noise reduction, anti-corrosion and anti-fouling techniques, computer applications and management aids.

BSRA's experience in the application of computers to routine ship design office calculations extends over a quarter of a century. In the 1960s BSRA pioneered interactive computing, using on-line terminals for these calculations. UK Shipbuilders were quick to appreciate the advantage of this method of working. Batch processing provides a means of validating a proposed design but interactive operation enables the programs to be used creatively while the design is being evolved and has resulted in a more rational approach to the design process.

A further development was the BRITSHIPS suite which comprises a comprehensive set of computer programs for ship design and production. More recently a computer-based system for steelwork design, detailing and generation of production information has been developed based on the CADAM interactive computer graphics system. This module now forms an integral part of the BRITSHIPS 2 suite.

Recently BSRA concluded arrangements with Computervision for the Wallsend Research Station to become one of the European Beta-test sites for APU developments. This is now underway.

BSRA has extensive computing facilities including:

On-line access to a range of mainframe computers including an IBM 4341 on site providing dial-up service

VAX 11/780

ICL PERQ

A range of microcomputers, including Ferranti F100L, ALTOS Series 8000

Intercolor 8063

Redifon Ci5000 hybrid digital/analogue system

PDP 11/34

supported by the following design drafting systems:

Kongsberg DP 300F/1845 draughting system

IBM CADAM

Computervision Designer V System

Ferranti Cetec- CAM X System

In addition to the research departments BSRA offers a wide range of technical services, in support of marine technology, on a contract basis worldwide. BSRA Technical Services support operators, builders and designers of ships and other marine structures in a number of ways:

Information Services
Design Support
Shipboard Engineering & Automation
Noise and Vibration
Corrosion and Fouling
Ship Trials
Service Performance
Shipyard Methods

Measurement and Instrumentation

Computing Facilities, and

Computing Packages

In addition, BSRA manufactures and supplies hull roughness analyser gauges for the quantitative assessment of hull surface condition. The ship design analysis programs, known as SFOLDS, are supplied with an ALTOS microcomputer as a complete hardware/software package.

1. INTRODUCTION

BRITSHIPS has been used, as an integral part of their design and production procedures, by UK shipyards for a number of years, some of the BRITSHIPS modules are also used overseas. It consists of a comprehensive system of computer programs for ship design and the support of ship production using modern methods of manufacture with numerically controlled (NC) machine tools. BRITSHIPS has been developed with the practical assistance of shipbuilding managers and combines the expertise and experience of these people with up-to-date computer technology.

BRITSHIPS 2 supports the shipbuilding process from the design of the hull form through design analysis, steelwork design, production definition of the hull form, lofting, piping, to assembly drawings and sketches, and production and materials requisition information.

The BRITSHIPS 2 system and the tasks performed by each of the major modules which it comprises are described in Section 2.

A list of the design analysis programs, known as SFOLDS, together with a short description of each program,‘ is contained in Appendix 1.

2. BRITSHIPS 2 - SYSTEM OUTLINE

2.1 The Modules

The BRITSHIPS 2 system, see Figs. 1, 2 & 3, consists of seven major modules linked through common data files which constitute the system data store. Some of the modules may be run as self contained sub-systems. This means that it is not necessary to implement all the modules at the same time or in the same location although in practice certain groups of modules would normally be run together.

The shipyard may select the modules most relevant to its needs and may implement them progressively.

2.1.1 The BRITSHIPS 2 modules are:

MODULE NAME	TASKS PERFORMED
SFOLDS (Ship Form On-Line Design System)	Routine ship design calculations
BRITFORM	Generation and manipulation of hull form geometry
BRITGRAPH	Steelwork design including scantling determination, detail design, fabrication and assembly

	details, creation of piece parts using an interactive graphics system
BRITFAIR	Lines Fairing, and production definition of the hull form
BRITSHELL	Shell arrangement, longitudinal definition and shell plate development
GOLD (Geometric On-Line Definition)	Interactive definition of steelwork piece parts and solution of design problems in geometry
GOLDNEST	Interactive nesting of piece parts within a rectangular plate and defining of cutting sequence
SPIN	Manufacturing and materials ordering information for ships pipework

2.2 SFOLDS

SFOLDS is a suite of programs for ship design analysis calculations

which are arranged for use either in conventional batch processing mode or interactively on-line from a computer terminal.

Programs are provided for hydrostatics, stability, longitudinal strength, tank calibration, launching, grain calculations, etc. Other programs enable preliminary offsets and lines drawings to be generated for forms conforming to the Revised and Improved BSRA standard series or the American Series 60. For these forms powering data can also be derived based on comprehensive model tests for the series.

SFOLDS programs use a common hull form definition to minimise data preparation. When the design has been finalised the offset data are transferred to the system data store for lofting by the BRITFAIR system.

The main SFOLDS programs offer the user a choice of output options at run time and there are programs for listing outputs in special formats, e.g. HYTAB and KNTAB (Appendix 1). Any of the data stored on file may be selectively listed.

The SFOLDS programs which are now in regular daily use by over 50 organisations throughout the world are written in a highly portable version of FORTRAN IV and have been implemented on the following different computers:

IBM 4341

IBM System 370

ICL 2900 new range including 2903 and 2904

Honeywell 2000 Series

Honeywell 6000 Series

GE 400

Univac 1100

Prime

Hewlett Packard 2000

Control Data Cyber 170 Series

ALTOS Series 8000

The SFOLDS module comprises the programs listed in Appendix 1. Additional programs dealing with seakeeping, vibration, propeller design etc., are also available.

2.3 BRITFORM

BRITFORM is the hull form generation and manipulation module. The BRITFORM system allows the user to define a hullform by means of a series of space curves in the three orthogonal planes (i.e. sections, waterlines and buttocks) together with boundary curves which define the limits of the hullform (i.e. stem, and stern profiles, flat of side, and flat of bottom).

The BRITFORM system is intended to be used by hullform designers/ draughtsmen and is therefore fully interactive with maximum use

being made of graphics facilities. The user communicates with the system by means of a simple, user-oriented, command language allowing him to display, manipulate and interrogate any of the curves defining the hull form directly on the graphics screen. The approach is similar to that used in creating a lines plan manually so that the transfer to using the BRITFORM system is relatively straightforward.

The BRITFORM system allows the designer to qucikly and accurately define the hullform. To achieve this the user manipulates a series of space curves which define the hullform in much the same manner as when constructing a lines plan manually. The space curves defining the hullform are:

(i) sections, buttocks and waterlines, i.e. curves lying in planes in the X, Y and Z directions.

(ii) the stem and stern profiles which define the limits of the hullform

(iii) the user may also define any or all of the following:

(a) stem and stern radii and tangent curves which are to be used in the definition of the waterline endings

(b) flat of side (FOS) curve

(c) flat of bottom (FOB) curve

(d) knuckle (or chine) lines

(e) tangent lines

The BRITFORM system uses a parametric B-spline for the definition of the space curves defining the hullform. No knowledge of the spline mathematics involved in the system is required by the user of the system.

B-spline curves are used by the system because they have the following advantageous properties:

(i) the ability to easily manipulate the B-spline interactively on the graphics screen

(ii) provides a stable fit through uneven or irregular data

(iii) the ability for one B-spline curve to contain knuckles (slope discontinuities) or curvature discontinuities (i.e. the point where a straight,line, i.e. zero curvature, tanges to a circle, i.e. constant curvature).

(iv) the B-spline can be easily interrogated for properties of the curve such as co-ordinates of a point, the slope and curvature at a point and the area enclosed by the spline and a boundary.

The advantages of using the BRITFORM system can be summarised as:

(i) increased speed over manual draughting methods

(ii) better accuracy since all data is stored to a high level of precision

(iii) ability to easily interrogate hullform properties, i.e. offsets, sectional areas, etc.

(iv) ability to easily produce information for other computer systems requiring a definition of the hullform such as hydrostatic calculations, etc.

(v) drawings can be produced at any scale directly from the stored information

The system has been developed on a VAX 11/780 computer, and currently operates using a Tektronix 4114 terminal. Work is currently being done to provide an implementation based on IBM mainframes.

The interface with BRITFAIR can be used to introduce, more flexibly, production details and is a necessary link to the BRITSHELL, BRITGRAPH and GOLD modules.

2.4 BRITGRAPH

BRITGRAPH is the steelwork design module.

Since 1968 a major portion of the UK Shipbuilding Industry has been using the BRITSHIPS system with its numerical methods to assist in the definition of the hull form and the definition of piece-parts. A logical extension of the system was to integrate the steelwork design and drawing office functions with the lofting activities using interactive draughting techniques. A major development along these lines has been jointly carried out by Swan Hunter Shipbuilders and BSRA, under the sponsorship of British Shipbuilders.

The steelwork design system incorporates an interactive draughting module and this is the designer's principal means of communicating with the system. For the implementation at Swan Hunter Shipbuilders the CADAM interactive draughting package was used.

A computer graphics system can significantly improve productivity in the production and modification of the several hundred drawings required to communicate design information to the customer, regulatory authorities and the shipyard's own production departments. A more important benefit from a shipbuilder's point of view derives from the fact that drawings created using a graphics system are stored in a machine-readable form as computer files. The geometrical, numerical and text data files once created in a drawing office may therefore be used in other computer processes. The system developed

enables the drawing data, produced by the draughting module, to be used directly for technical and administrative purposes.

The well established BRITFAIR (Lines Fairing) and BRITSHELL (Shell Lines and Shell Plate Development) modules have been retained and are integrated into the overall system.

The interfaces between the various modules are shown in the schematic information flow diagram, Fig. 1. Fig. 3 presents an overview of the BRITSHIPS software together with the interactive graphics data base and the BRITSHIPS data store.

2.4.1 STEELWORK DESIGN - SCANTLING DETERMINATION AND SCANTLING DRAWINGS

The preliminary definition of the hull form and arrangement of the primary structure is held in the system as a three-dimensional 'wire model'. Typically, the topological model will define the moulded lines of all structural frames, decks, tank top, bulkheads, girders, stringers and longitudinals. These moulded lines are defined in a topological manner, e.g. a bulkhead might be defined as extending from a deck to the bottom shell. The advantages of topological modelling are that if, for example, the hull form is modified or a deck re-positioned as the design develops, then providing the topology is unchanged, the geometry of the three-dimensional model can be regenerated from the definitions already input. CADAM drawings, Fig. 4, showing the moulded lines of any

required structural section of the ship are generated automatically from the wire model by the system. Designers using the standard CADAM draughting facilities continually enhance the structural section to produce the steelwork drawings, Fig. 5.

The first steelwork drawings normally produced within the system are scantling drawings, Fig. 6, for classification approval. These drawings are developed on the basis of the moulded outlines provided by the 'wire model' and therefore maintain full-scale precision in their numerical representation in the computer. There are no facilities in the system at the present time for the calculation of scantlings in accordance with Classification Society rules. It is assumed that scantlings will be determined using programs, such as LRPASS, provided by Lloyd's Register of Shipping or similar Rules/programs provided by the other Classification Societies. The scantling data are then input to the data bank.

To assist in the more detailed structural analysis methods such as finite element analysis the CADAM system provides a very effective finite-element, mesh-generation module. This interactive module creates element data in the required format for direct input to the LR-NASTRAN FEA package.

The programs related to steelwork design and definition provide a range of facilities which are invoked via the screen. These are:

(i) generation of an outline midships section

(ii) calculation of weight per metre of ship length

(iii) calculation of second moment of area of section, and section modulus.

(iv) stiffener selection routines - the designer is presented with data for a range of standard sections which match the required modulus. Cost related indices and sectional area information enable the user to select the most suitable section (Fig. 7). The profile for the chosen section can then be generated and added to the existing structural information on the drawing.

(v) calculation routines - to calculate the section modulus of built-up girders, double plate bulkheads and corrugated bulkheads.

2.4.2 GENERAL ARRANGEMENT

The General Arrangement, Fig. 8, is based on the same three-dimensional model and deck outlines are therefore defined to full-scale precision. Areas of this drawing may be scaled up as a basis for detailed arrangement drawings, thus promoting consistency throughout the design.

2.4.3 ARRANGEMENT OF SHELL

The next phase of the design is the arrangement of straking of shell plates. The straking arrangement is developed at the interactive graphics screen using the body plan derived from the three-dimensional wire model. Hence a plate-line, body plan is created, Fig. 9. The information held on the plate-line, body plan is interpreted by a system program to create three-dimensional representations of all the relevant lines on the moulded surface. The 3D data are used by the shell plate development programs and enable a shell expansion drawing, Fig. 10, to be generated. NC tapes for the developed shell plates containing all rolling and marking information are produced using the BRITSHELL module.

Steel requisitioning is started by abstracting individual piece parts from the steelwork drawings and storing them in the computer, to be recalled later to the screen for interactive nesting. A typical steel requisition print-out is shown in Fig. 11. The requisitioning information is available on the computer to be interfaced with a company's commercial system for purchasing and material control.

The unit drawing, Fig. 12, is a direct development from the corresponding scantling plans. Sub-assemblies are defined from the unit drawing and programs take information from the two-dimensional drawings representing two or more views of an assembly and create a three-dimensional representation from which

assembly sketches may be produced in isometric form, Fig. 13.

The breakdown of the unit into sub-assemblies and piece parts requires the addition of a significant quantity of non-graphic information. This is facilitated by the 'attribute' facility in the CADAM system which allows text data to be associated with particular elements of a drawing and by the ability to process the stored information on a drawing by purpose-written application programs. An example is in the assignment of 'number off' against each item on the parts list generated from the drawing. Other important attributes which may be passed on to other production control systems are joint length (or weld length, weld volume), weld type and steel weight. A typical parts list is shown in Fig. 14.

2.4.4 DESIGN FOR PRODUCTION

It has always been the aim of designers to incorporate as many production-kindly features as possible into their designs. Short lead times and lack of information and facilities have usually mitigated against these ideals. However, the advent of computer-aided design systems, incorporating graphics terminals, has provided the tools which can bring about a realisation of the concepts of design for production.

The system provides the user with the opportunity to incorporate in a design the production methods and facilities of the shipyard by providing guidance information, which will lead to production-

kindly designs, as the drawing is developed. A number of facilities are provided.

(i) Technical standards - these have been designed using production engineering concepts in order to:

(a) assist in the efficient use of numerically controlled machines

(b) ensure that quality and repeatability are maintained

(c) promote the stockpiling of standard parts

The standards presently covered by the system are:-

Stiffener profiles
Stiffener notches, lugs and collars
Manholes, covers and small hatches
Lightening holes, drain holes and scallops
Brackets
Stiffener end trim, scarphs and connections
Plate edge preparation codes
Drawing symbols and conventions

The technical standards are stored in a topological form and their geometry is obtained by specifying certain key dimensions. Fig. 15 is a table of the standard notches

currently held in the system. It shows the various applications and types of bar for which the notches are suitable. For example, a notch which is to be slack with a seam extension has the code NSlBA. By specifying the code, followed by the size and type of stiffener to pass through the notch, the correct geometry of the notch is automatically generated and can be added to the drawing. At the forward and aft ends of the ship, where longitudinals pass obliquely through the notch, the notch dimensions are corrected automatically to take account of any obliquity.

(ii) Information on shipyard facilities - the data base may contain, for example, a set of drawings and specifications of the layout of the shipyard, the workshops and machines. These data are available at the graphics screen and allow the designer to quickly ascertain the capabilities of a particular machine or the constraints of a workshop. The facilities information would indicate the cranage available, the types of transport, floor area available, size of doors and openings and any other constraints which would influence unit or sub-assembly size and weight.

(iii) Production engineering standards - these would consist of sketches showing company-approved methods for the assembly of typical structures together with process flowcharts showing the sequence of operations, Fig. 16. A library of production engineering standards specific to individual yards

could be built up covering minor assemblies, sub-assemblies, and units for a range of ship types and sizes.

(iv) Manipulation of drawings on the screen - the user has the means of rotating an assembly in three dimensions on the graphics screen and hence determine the best orientation for manufacture on the shopfloor. In this instance the user is able to assess the quantity of downhand welding as opposed to positional welding and to work out a strategy which will reduce welding costs.

2.4.5 LOFT WORK

Piece parts to be cut using NC profile burning machines may be nested using the CADAM facilities or the GOLDNEST facility as described in Section 2.8. If the facilities in CADAM are used the loftsman defines the order in which parts are to be marked and cut by driving the tool head round the piece parts presented on the graphics screen, and inserting the auxiliary functions in the appropriate places.

Punching of the NC tape can be left until shortly before it is required so that any last minute modifications to the steel parts, such as the addition of pipe penetrations, may be inserted.

An alternative to using the CADAM facilities is to use the GOLD and GOLDNEST modules. If this option is chosen the piece parts defined in CADAM are converted to a GOLD definition prior to using the

GOLDNEST module. One advantage of using the GOLD module for piece parts definition is the facility to create oft-used parts as macros having a topological structure. A whole range of structural macros covering floors, web frames, longitudinal girders et. could be developed by the yard for incorporation into ship structures. Further details of GOLD and GOLDNEST will be found in Section 2.7 and 2.8 respectively.

Instructions for cutting flame-planed plates and subsequently joining them into panels may be prepared using special pre-formatted drawings. As each plate is identified on a flame-plane drawing, a check may be made to ensure that material has been requisitioned. The drawing includes a sketch indicating what is to be produced together with precise numerical data, Fig. 17.

Stiffeners are processed in much the same way as flame-plane plates. The system generates a stiffener preparation card with sketch showing the appropriate end trim for standard connections, Fig. 17.

For parts produced on NC profiling machines, the marking information is incorporated in the control tape and marking performed by the machine. Other lining off information may be included on the flame-plane and stiffener preparation cards and may also appear on the assembly sketches.

2.5 BRITFAIR

BRITFAIR is the lines fairing, hull surface definition and interpolation module, and performs the lofting functions of:

- fairing the lines
- adjustment of the form to accommodate constructional details at stem and stern
- incorporation of production engineering requirements such as flat areas and knuckles
- definition of decks, flats, stringers, hopper tanks and other intersections with the moulded surface
- interpolation of building frames
- deformation of an existing hull form

The module is preferably used interactively from a terminal since this gives the user maximum control over the processes.

Fig. 18 is an example of the production-level definition created for a bulk carrier using BRITFAIR.

BRITFAIR takes in offset data defining the hull form at the normal

design level of detail (e.g. from BRITFORM or that used for making the model for tank testing) and outputs a complete production definition. BRITFAIR creates a series of structured data files which are subsequently accessed by the BRITGRAPH, BRITSHELL and GOLD modules.

Processing by BRITFAIR to create these files in the data store is essential to the application of BRITSHELL and the optimum use of GOLD in piece-part definition.

The data on file may be displayed graphically in various forms of drawing, on any required scale and the detailed numerical information available in the 'loft books' is output by the system.

2.6 BRITSHELL

BRITSHELL is the Shell and Longitudinal Definition Module and is used to:

- define and verify the seams, butts, longitudinals or any general line on the hull surface

- describe the straking arrangement, and

- develop the shell plates and produce the NC tapes and listings for plate cutting

generate manufacturing statistics such as length of profile, percent scrap

generate shell jig setting information

Typically the procedure for using BRITSHELL is for the positions of the seams and longitudinals to be obtained from the plate edge body plan and shell expansion drawing. These lines are adjusted and verified by use of the BRITSHELL facilities and then the individual plates which constitute each strake are identified to the system using the simple user language which minimises the amount of numerical data that has to be supplied.

Typical output for the shell arrangement, longitudinals and deck-at-side lines was shown in Fig. 9.

The shell arrangement already defined will be used as a basis for the development of the shell plates and the generation of plate marking information through a further application of the BRITSHELL input language. A plate may have up to seven sides. There is also provision for specifying the plate thickness and the grade of steel to be used. A margin of additional material which can be trimmed during erection may be specified on one or more sides. The cutting margin is also specified for each batch of plates. This is the amount by which the nominal length and breadth of the ordered plate should exceed the theoretical dimensions of the minimum circum-scribing rectangle. It provides for the width of the cut and allows

for any mal-alignment of the plate on the burning table and for departures from the nominal dimensions. A marking statement specifies which of the lines already defined on the moulded surface should be transferred to the developed plate. A check drawing of a developed plate may be produced on the screen of a display terminal. Steel/ordering information and plate preparation statistics will be generated for each developed plate. Depending on the method of flame cutting used in the shipyard the actual manufacturing data output will consist of either an NC machine control tape, an optical template drawing, or a tabular statement of co-ordinates for manual marking. The same procedures will be used for the development of any longitudinals which do not lie in one plane.

Rolling set information can be drawn on the plate itself from the NC tape. Alternatively this information can be output in tabular form.

BRITSHELL also generates the Longitudinal Information Files necessary for the automatic notching facility of the GOLD processor.

2.7 GOLD

GOLD is the piece parts definition, nesting and general geometric problem solving module.

GOLD (Geometrical On-Line Definition), Fig. 19, is the parts definition

module of the system, and takes advantage of the latest developments in language processing techniques to provide a system which may be used either in conventional batch mode or on-line from an interactive graphics terminal.

There are two approaches to part programming, the first requires detailed information for each part in the form of working drawings. This information is then coded as a set of unique instructions which result in the replication of the original information in the form of a drawing or control tape. The other approach is to use a system for defining the part geometry in algorithmic form, i.e. it is the method of constructing the geometry which is defined to the computer rather than the actual shape of the individual part.

GOLD allows a gradual progression from the first approach to the algorithmic mode. Initially, part-programmers coding individual parts from fully dimensioned drawings need only be instructed in a few simple statements defining points, circles and contours. These enable quite complex shapes to be defined by terse statements which specify dimensional data for the key features of the outline. As they progress to more general work, part-programmers may be introduced to the geometry and logical features which allow parts to be defined in terms of more basic data and construction rules.

The geometry of the faired hull form and structural arrangement defined by BRITFAIR and BRITSHELL is accessible to GOLD. Elements of this geometry may be referenced by name when writing parts

descriptions and require no further definition. Frame shapes and the points at which each longitudinal intersects a transverse frame may be referenced in this way. The stored longitudinal scantling information enables the appropriate 'notch' profile to be generated automatically where transverse webs are penetrated by longitudinal stiffeners. The dimensions of the notch will be adjusted by the system to allow for the obliquity of the bar at the point where it passes through the transverse material.

A further development has been to reduce the extent of part programming instructions needed to define large steelwork components with many detail cutouts. Often-used cutouts required for drainage, passage of stiffening members etc. are described in part-programming language by the use of macros. In normal circumstances, these are called as required each time the detail occurs, and obviate the need to part program the cutout each time.

Common practice is to build the description of a new component calling the system macros as necessary, and describe the remaining outline in part programming language by reference to the hull file, or by defining the boundaries.

The Structural Part Macros (SPM) development is in effect a suite of large macro programs, defining items such as floors or longitudinal girders in double bottom structure. Programs have been created, whereby the parts programmer can call the relevant SPM full description, and by defining a small number of parameters

create the complete part description. The computer program is used interactively with the hull file, GOLD system, and existing low complexity macros. The output from the SPM is produced directly on a punched paper tape for the numerical-control profiling machines, or as optical 1/10 scale templates as defined by the user.

The power of the GOLD system also extends its use beyond parts definition to general design problems involving complicated geometry.

2.8 GOLDNEST

GOLDNEST is the module for the interactive nesting of piece parts. Parts may be nested as they are programmed or they may be stored and the nesting done later using a separate interactive nesting facility GOLDNEST. This operates as post processor and does not require the reprocessing of the original parts programs.

Certain properties of the parts such as the lengths of profile and weight are calculated and stored along with the grade of material, thickness and the completed definition of the part. These are used by GOLDNEST to generate manufacturing statistics.

GOLDNEST is operated from an interactive terminal equipped with either a display screen or an A3 size plotter. The outlines of parts to be nested together are displayed and, by means of simple instructions input at the keyboard and the use of a cursor on the screen or plotter table, the required positions of the parts are indicated.

Parts may then be repositioned until a satisfactory nesting has been achieved. Parts may be replicated or mirrored as required in the course of nesting. Finally the order in which the parts are to be cut is indicated. Broken lines are used to represent rapid movement of the cutting head between marking and burning operations. The output from GOLDNEST is a file of cutter-location data for the nested arrangement. This is then post-processed to produce machine control instructions for either an NC machine or a drafting machine on which an optical template is to be drawn.

Various auxiliary programs may also be brought into use for example, to generate the marking information required for the bending of frames by the inverse-line method or to provide the data required for setting pillar jigs for curved assemblies.

2.9 SPIN (Shipbuilding Pipework INformation)

2.9.1 INTRODUCTION

Pipework manufacture and installation work represents a substantial volume of work in shipbuilding, and most shipyards employ a mixture of computer control and mechanisation through numerically controlled bending machines, flanging machines and so on.

The traditional method of design and detailing of piping systems comprises two phases: pipework design and pipework manufacturing information. The design phase requires the production of composite

(general arrangement) drawings or physical models of the machinery space equipment, the bounding steelwork, and the pipework which interconnects the various items of equipment.

Manufacturing information comprises the preparation of individual pipe sketches together with details of materials required and other manufacturing information.

For several years now several UK shipyards have been using a computer system to facilitate the preparation of production sketches, supported by material and pipeline equipment lists, for ordering, production and progressing requirements. The computer package, known as 'Shipbuilding Pipework INformation' (SPIN), was developed by BSRA in conjunction with Swan Hunter Shipbuilders, who are using the package as routine on ship contracts.

2.9.2 'SPIN MODULE

SPIN is a computer package, written in standard FORTRAN, which facilitates the manufacture and installation of ships' piping. It reduces, or may eliminate, the need for routine hand drawing of pipe piece sketches and the manual preparation of lists of components, materials and pipe weights.

SPIN has been designed as a general-purpose package for use in connection with all merchant ship pipework systems and, except for certain specific systems, also for Naval ship pipework. As

such it should be usable by all shipyards.

The actual user of the system is the engineer who requires data to be processed and piping information produced. The user needs to know only what information has to be input and the format. In engineering terms this is straightforward insofar as it comprises the geometric, dimensional, materials and fitting details of the piping systems.

The input to SPIN comprises:

(i) Details of the standards for piping and fittings used by the company concerned, together with stock numbers. This is input once and for all at the outset, but may be modified as required at any time. Subsequently, the material titles and stock numbers will be reproduced on the output documents.

(ii) Details of the specification data for each pipework system within a particular ship. Within some yards it may be possible to define a set of standard specifications which will normally be applied to all ships. If the latter applies this again is a once-off operation.

(iii) Details of the dimensional characteristics of pipe-bending machines used in the particular shipyard, i.e. the range of tube sizes covered and, for each size, the bending radius, clamp length and minimum trailing length.

(iv) Details of the dimensions and geometry of all piping systems for the given ship, lifted from the composite drawings of the machinery arrangements, or physical models if these are used. To facilitate the input of pipework geometry from manually-prepared drawings a geometry take-off language is provided. Using this information the system creates and stores a numerical definition of the piping arrangement.

The output from SPIN can include:

(i) Manufacturing sketches for individual pipes including details of the types and quantities of materials, flanges and components to be used, together with tube bending data. If required, details of individual pipe weights, centres of gravity and complexity factors may be automatically provided.

(ii) Separate lists of pipes and fittings, together with stock or order numbers required for ordering and production purposes.

(iii) Arrangement drawings of any desired subset of piping may be obtained for use during installation. These drawings may be to any scale and show any required views.

The main benefits of SPIN are:

The manual effort required and the elapsed time to produce manufacturing drawings is reduced and hence increased lead time is obtained which facilitates planning, estimating, ordering and outfitting.

Once data and information are created, verified and stored in the computer it becomes secure and ensures freedom from manual errors.

The processed information may be used for other production and scheduling purposes.

Drawings are of a consistent nature and pipe manufacture is facilitated.

2.9.3 DEVELOPMENTS

At present, the application of the system on a given contract begins when the pipe arrangement drawings or physical models have been completed. SPIN makes no contribution to the arrangement process, nor does it carry out any checks on the possibility of pipe clashing or fouling. The latter problem obviously requires the use of sophisticated computing procedures in association with a three-dimensional geometry model.

To facilitate the input of piping geometry to the system an interface

package has been written to provide a direct link to the CADAM piping module. As a result there has been a substantial reduction in the effort required to input information to SPIN. Swan Hunter Shipbuilders are presently using both the CADAM module, for piping arrangements, and SPIN, for production and manufacturing information, in a production environment.

3. BENEFITS AND SAVINGS

The principal benefits to be expected from BRITSHIPS 2 are:

- reduction in lead time
- reduction in loft costs
- reduction in production costs
- reduction in direct technical costs

BRITSHIPS 2 has been designed to improve performance in a number of ways by:

- provision of information to production in a form most suited to the activities of individual work stations
- improved design for production incorporating production and value engineering considerations

- improved standards and increased use of standards

- reduction in technical modifications and error correction

- reduction in material requirements through improved nesting facilities

- reduction in Mould Loft manhours

Reference 4 indicates that at the Swan Hunter Shipyard the savings which are considered to be attributed to the use of the system for steelwork design amount to approximately 5% of the total steel cost of the ship.

4. USE OF THE SYSTEM IN PRODUCTION

As noted previously in the Paper, the BRITSHIPS system has been used by UK shipbuilders, both large and small shipyards alike, for some considerable time. The steelwork design module was developed in conjunction with Swan Hunter Shipbuilders and they are presently using the module in their shipyard on the River Tyne. Up to this point in time, the steelwork module has been used on some three ships within the yard.

Swan Hunter Shipbuilders build at several different locations and

currently have 31 IBM 3251 terminals - 27 at their Wallsend yard and four at their Hebburn yard.

The Hebburn yard is on the opposite bank of the river to Wallsend and the link between the main computer and the terminals is via a 48 K baud fibre-optic link. The distribution of terminals in the yards are:-

(a)	Research and Development	2
(b)	Loft	5
(c)	Hull Design Office	2
(d)	Engine Design Office	2
(e)	Drawing Office	16
(f)	Training Purposes	4

5. FUTURE DEVELOPMENTS

BSRA, as part of its role in providing CAD/CAM support for the UK shipbuilding industry, is carrying out further work to extend the BRITSHIPS system. At present it is planned to extend the use of Computer Graphics to the design and definition of engineering systems for ships and offshore structures.

When the work is completed facilities will exist for the definition of schematics and identification of fittings, components, control loops, sensing points, etc. It will be possible to produce fitting lists, control loops lists, etc. as well as details of the materials of the material to be ordered.

Layout and Arrangement Drawings may be prepared, showing various views of the ship structure with block outlines, and standard symbols for positioning machinery etc.

A detailed definition of each system in the ship will be possible. The facilities provided will be sufficient to enable the generation of information for production using the features available with CADAM draughting systems.

Facilities will also be provided for carrying out technical design calculations based on the drawings and data defined. These calculations may be carried out at any time, provided the appropriate data is available, and the results stored for future reference. A large range of design calculations are expected including calculations such as cable and pipe sizing; weight and centroid values, shaft alignment, pipe friction loss etc.

Production information involves the generation of the appropriate information required for the production of workstation drawings, component parts lists, etc. This may well involve the use of individual yard systems and hence it will only require an

interface from data generated by this project to be used by the yard systems.

Interfaces will be provided for such items as Pipe Stressing Programs, and TOPCAT (manufacturing and ordering information system for electric cables).

A further stage in the development of BRITSHIPS will be to provide facilities for incorporation in the initial stages of Ship Design, bringing together software for numerical hull definition and design analysis calculations including an assessment of the hydrodynamics.

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APPENDIX 1 - DESCRIPTION OF SFOLDS PROGRAMS

PROGRAM NAME	PROGRAM NOTICE NUMBER	BRIEF DESCRIPTION
APPROVE	PN 15	Program to check the consistency of the data in a DESIGN or PORTN file.
BALCO	PN 53	Program to calculate sinkages, changes in trim and changes in draft for compartments.
BENDS	PN 137	Program to calculate the longitudinal shearing force and bending moments in still water or waves.
BEST	PN 19	Program to calculate particulars of bulk carrier steelmass for a midship hold or for both full and empty holds.
BODY	PN 17	Program to produce ESSI tape for drawing a body plan.
BPLOT	PN 25	Program to produce a rough plot of a body plan and simple portion data.
BSAD	PN 60	Program to generate bending moment, shear force and deflection curves.
CFLOOD	PN 154	Program to compute damage and/or cross-flooding stability of a vessel. Pumping operation from one compartment to another or to shore is allowed.
COLLECT	PN 57	Program to collect and generate input to program TRISTA.
DAMAGE	PN 56	Program to calculate damage stability particulars allowing for waves, axis shifting, free trim and changes in free surface in partly filled or intact compartments.
DBAL	PN 67	Program to calculate predicted A-weighted noise levels in a ship's accommodation spaces.

DCRIT	PN 161	Program to calculate the damaged critical KGs based on IMO regulations.
DEFORM	PN 12	Program which uses the parent hull offset file data on the standard 23 stations to modify the form in order to derive a new form with specified form characteristics and principal dimensions.
DENSE	PN 108	Program to magnify the number of portions from existing ones to give better definition.
DLONSH	PN 11	Program to compute Velocity time curve during launching using McNeil energy method.
ECEVAL	PN 145	Program to make an economic evaluation of a proposed ship design.
FGRAIN	PN 152	Program to calculate the transverse and vertical grain heeling moments for filled compartments in accordance with the SOLAS 1974 criteria.
FLOOD	PN 7	Program to calculate the floodable length curves from the BONJEAN areas, using the SHIROKAUER method.
FREEBD	PN 15	Program to calculate the summer freeboard according to the 1968 Merchant Shipping (Load Line) Rules.
GPORTS	PN 156	Program to produce unformatted binary files required by programs CFLOOD, DAMAGE and WSTAB.
HOLDS	PN 170	Program to create DEADWT file or grain heeling moments using BIN1 & BIN2 from GPORTS.
HYDRE	PN 61	Program to calculate trimmed hydrostatics and sectional properties.

HYTAB	PN 23	Program to produce formatted tables of the particulars in A4 format using the output file created by the HYDRE program.
ICRIT	PN 153	Program to produce intact critical KGs, maximum allowable deadweight moments, and table of allowable grain heeling moments in accordance with IMO criteria.
KNTAB	PN 24	Program to produce formatted tables of levers suitable for inclusion in a ship's stability information booklet.
LIFTOFF	PN 162	Program to digitise offsets from a body plan into a DESIGN file.
LINE	PN 130	Program to produce the ESSI file for drawing the lines plan of the offsets used in a DESIGN file.
LOAD	PN 155	Program to produce stability particulars and buoyancy curves stored in an unformatted binary BIN3 file.
LONSH	PN 74	Program to calculate launching particulars for a ship or any floating object for a series of travels down the launching ways.
MSHF	PN 63	Program to generate a basic hull form from BSRA's improved and revised standard series data.
MSPE	PN 3	Program to calculate power requirements and resistance particulars from BSRA's improved and revised standard series data.
OFFTAB	PN 109	Program which tabulates the values from a DESIGN file for any given ship, so that they are suitable for inclusion in a stability book.

OPDS	PN 131	Program to optimise the design of 4, 5 or 6 bladed propellers based upon the NSMB (Troost)
PARTS	PN 5	Program to create an offset file on the 23 standard displacement stations between the two transverse bulkheads specified, given the offsets for up to 50 stations in the ship's length.
PPESSI	PN 88	Produces drawing(s) from ESSI file.
REVERSE	PN 146	Program to reverse the order of the stations in the DESIGN file so that the AP and FP are transposed. Suitable for bow first launching calculations.
RIGS	PN 149	Program to produce simple portions defining standard shaped sections, typical of an offshore structure.
SFTOSK	PN 199	Program to use the BONJ, WEIGHT and DEADWT to create the TSEA file used by BRITSEA.
SPACES	PN 157	Program to generate simple portions defining compartment or tank spaces from DESIGN file containing displacement station offsets.
SR60	PN 10	Program to create a basic hull form from the US Series 60 data.
TANK	PN 9	Program to calculate tank calibration tables in terms of soundings or ullages for each compartment defined by simple portion data.
TRIMS	PN 150	Program which reformats the output produced by program TANK.
TRISTA	PN 22	Program to calculate the trim and stability particulars for given loading conditions.

WAYE	PN 171	Program to compute way end pressure using the Ratcliffe method.
WCURVE	PN 21	Program to generate a weight per unit distribution from the WEIGHT file and write this to file TWAYE2.
WINDOW	PN 86	Program to produce windowed ESSI file for a magnified drawing of a selected area in a drawing.
WSTAB	PN 54	Program to calculate the cross curves of statical stability allowing for waves, axis shifting, and fixed and free trim.
WTFIX	PN 169	Program to swing base line of WEIGHT file to give new WEIGHT file with required weight of LCG.
TONNAGE	PN 172	Program to calculate gross and net tonnage in accordance with 1969 International Tonnage measurements.

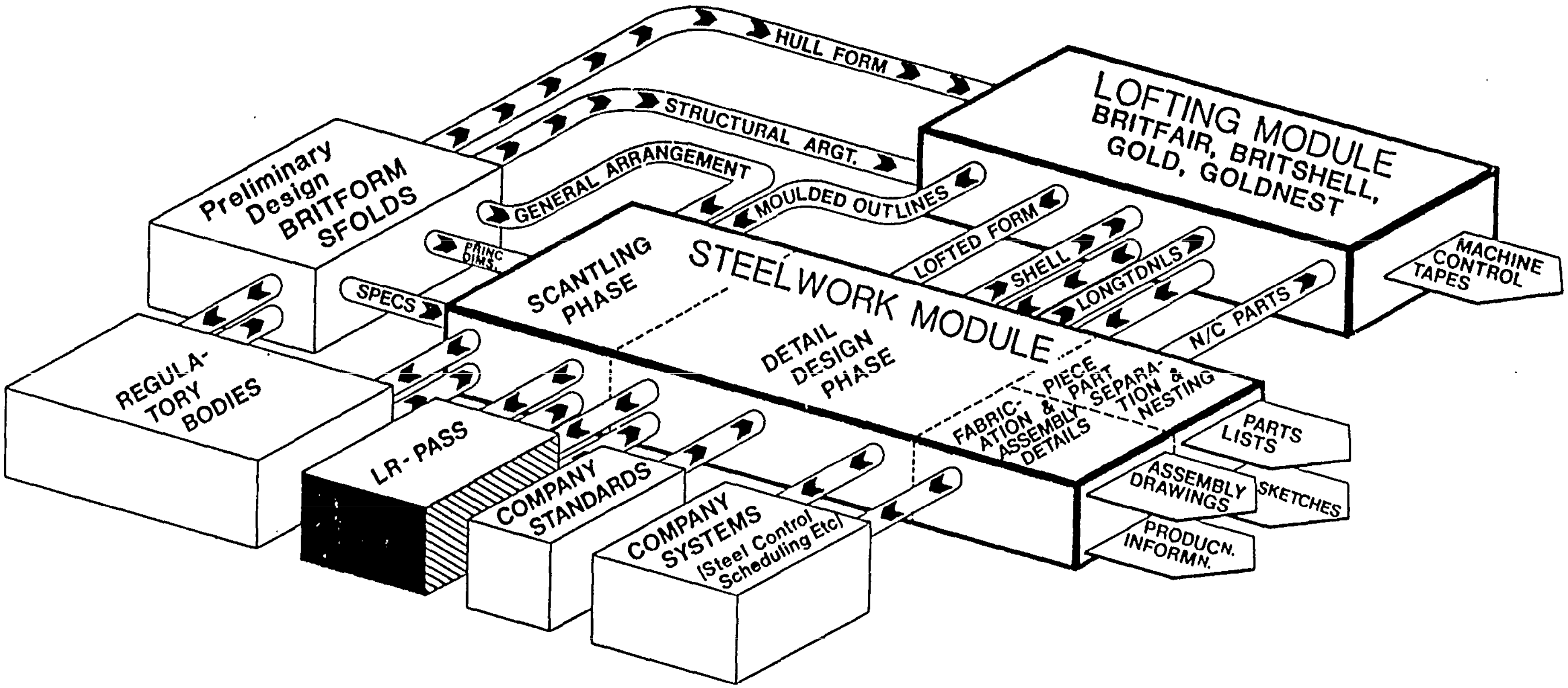
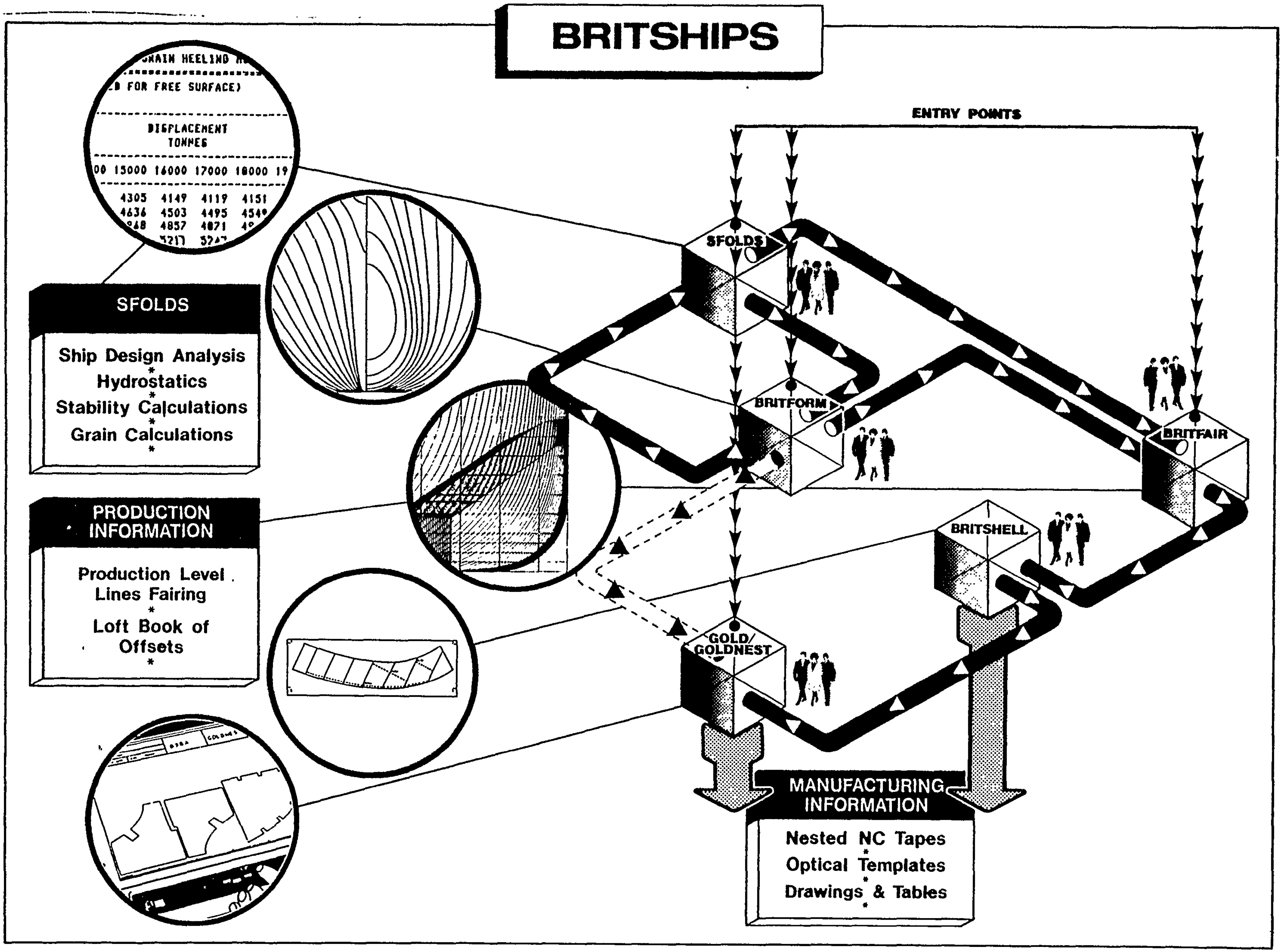


Fig.1 BRITSHIPS 2 INFORMATION FLOW

Fig.2


BRITSHIPS
ENTRY POINTS
FOR FREE SURFACE)
DISPLACEMENT
TONNES
15000 16000 17000 18000
4305 4149 4119 4151
4636 4503 4495
4857 4871
SFOLDS
Ship Design Analysis
*
Hydrostatics
*
Stability Calculations
*
Grain Calculations
*
PRODUCTION INFORMATION
Production Level
Lines Fairing
*
Loft Book of
Offsets
*
SFOLDS
BRITFORM
BRITFAIR
BRITSHELL
GOLD/
GOLDNEST
MANUFACTURING
INFORMATION
Nested NC Tapes
*
Optical Templates
*
Drawings & Tables
*

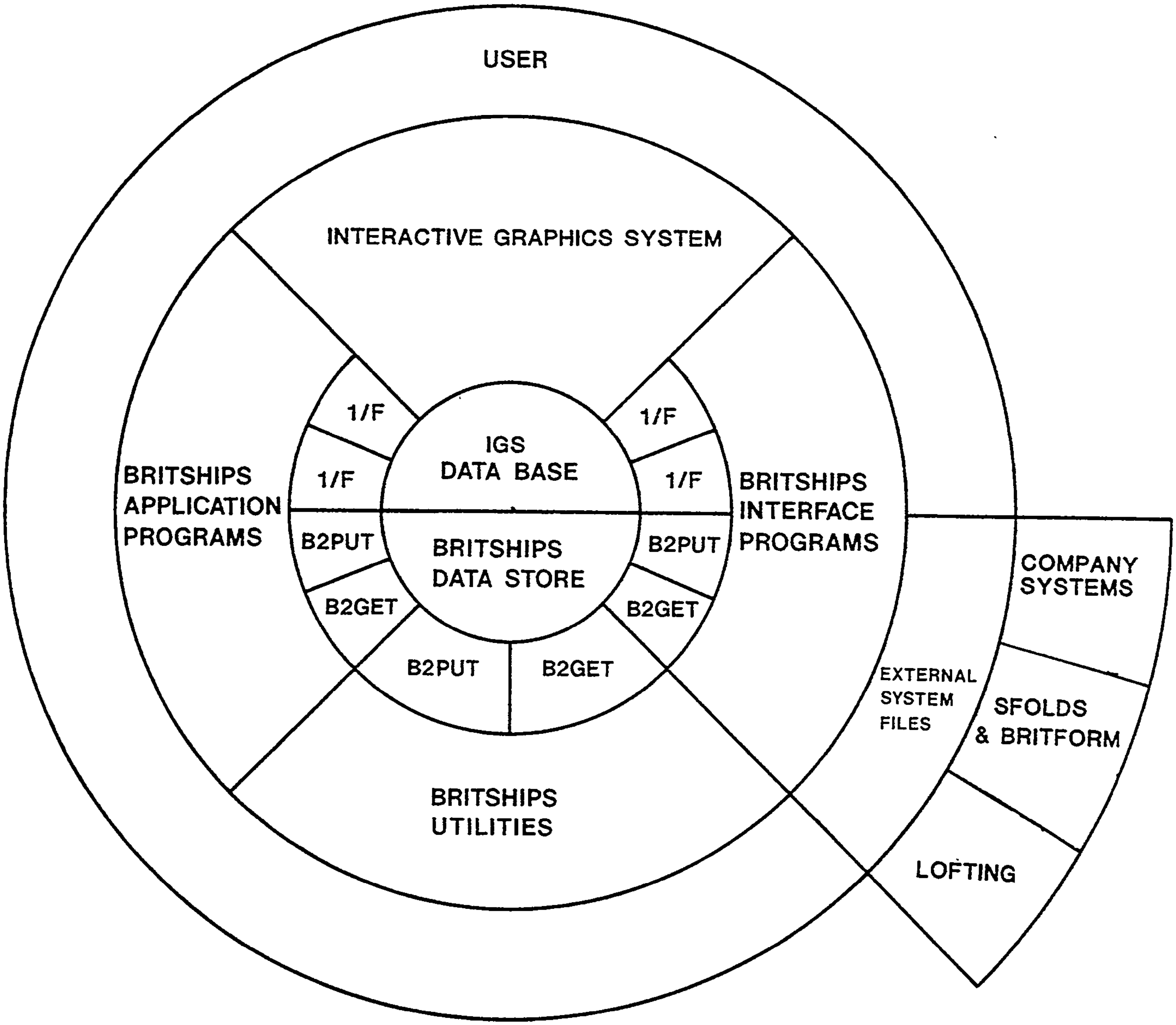


Fig.3 BRITSHIPS 2 SYSTEM OVERVIEW

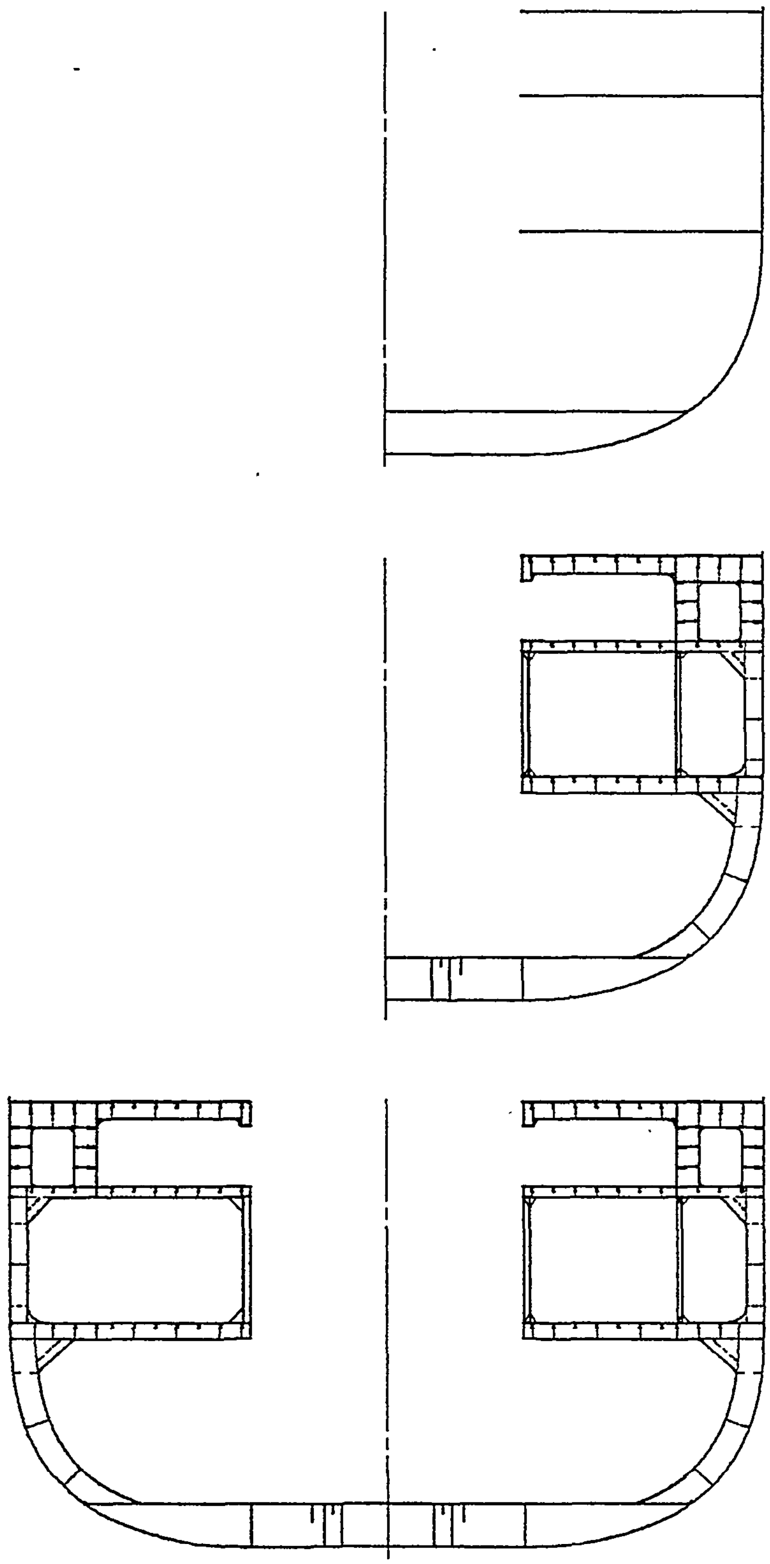
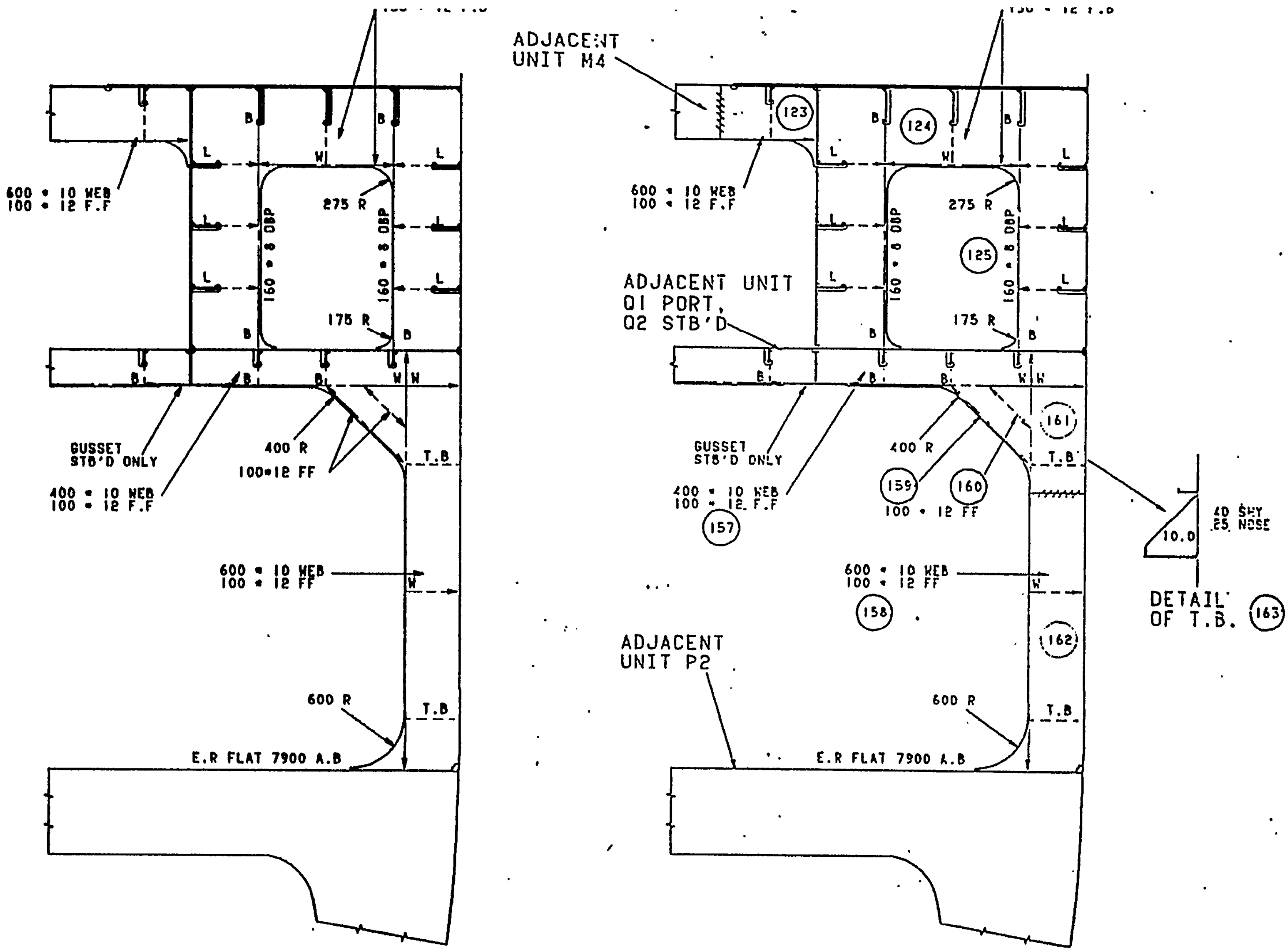


Fig.4 PREPARATION OF SCANTLING DRAWINGS

Fig.5



SECTION AT WEB 71 SECTION AT WEB 71

(a) PART OF TYPICAL SCANTLING DRAWING (b) PORTION OF A UNIT DRAWING WITH ITEM NUMBERS

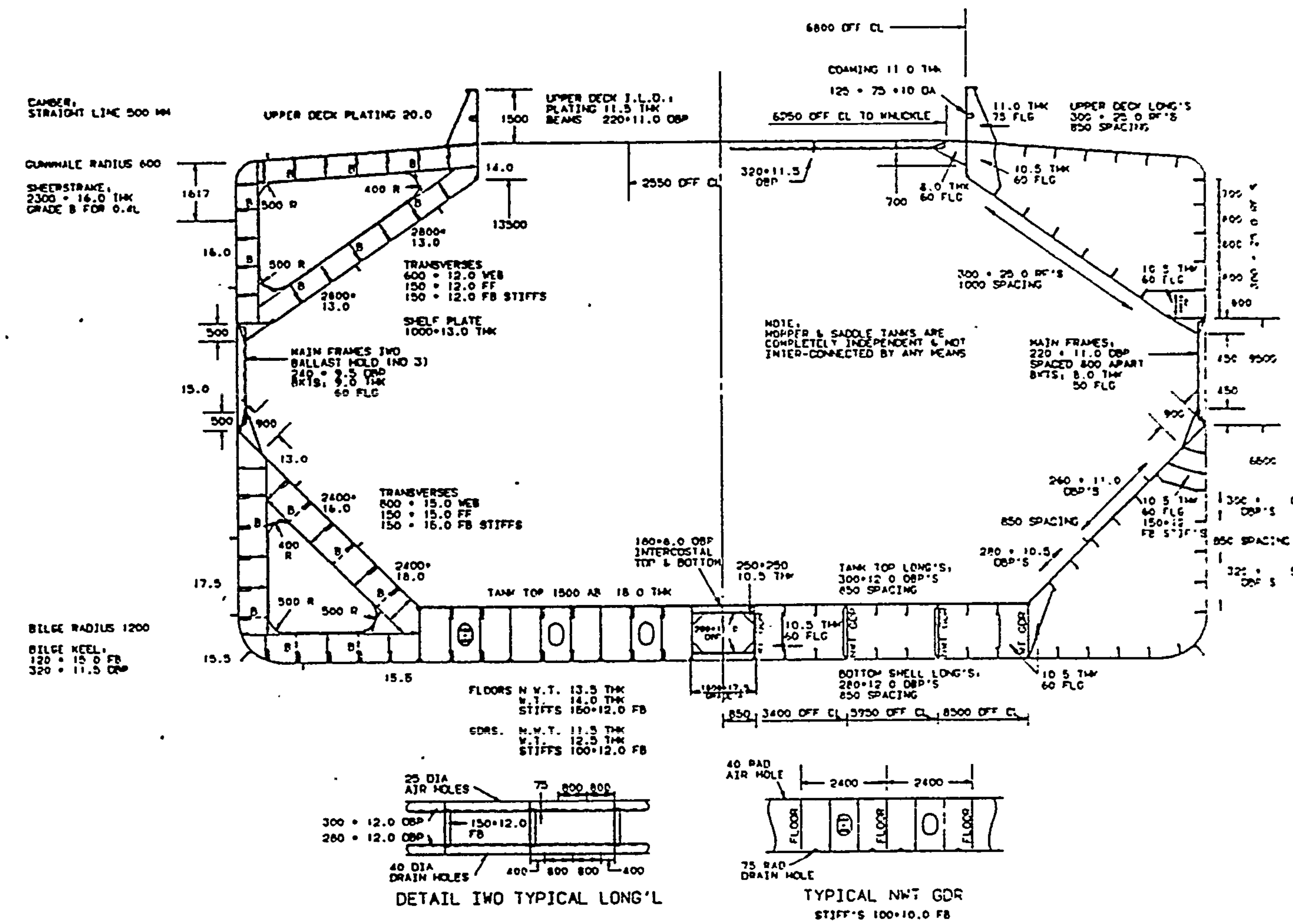


Fig.6 MIDSHIP SECTION

STIFFENER SELECTION PROGRAM

INPUT;

SECTION MODULUS REQUIRED: 580.0 (CM**3)

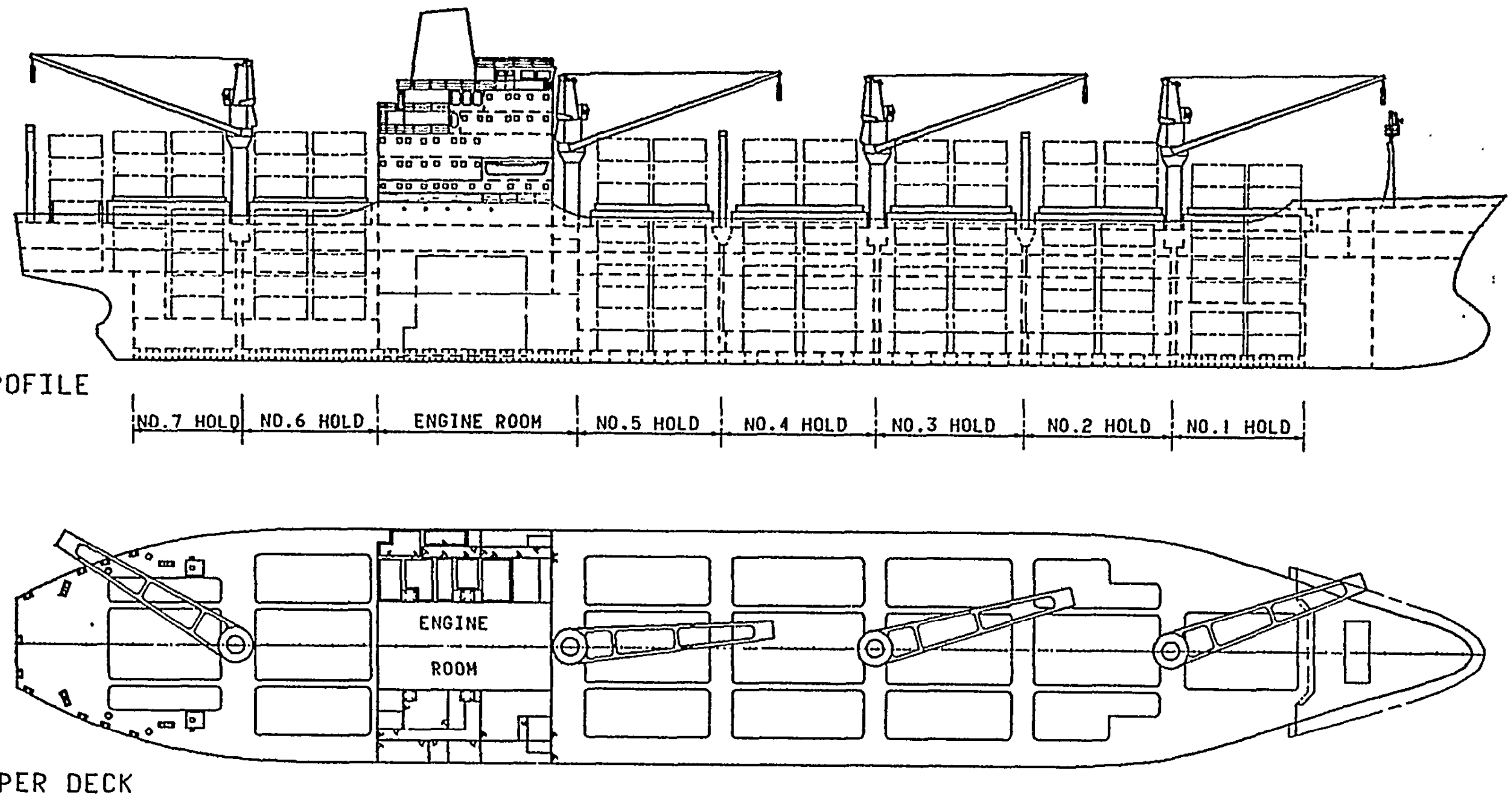
ASSOCIATED PLATING THICK; 15.5 (MM)

STIFFENER SPACING ; 850.0 (MM)

OUTPUT;

TYPE	STIFFENER SIZE			PLATING WIDTH	PLATING THICK	TOTAL AREA	SECTION MODULUS ZCALC	SECTION MODULUS ZREQ	COST INDEX
	(MM)	(MM)	(MM)	(MM)	(MM)	(SQ.CM)	(CM**3)	(CM**3)	
OA	200. *	150. *	18.0	620. *	15.5	156.0	663.6	580.0	13140.0
FB		300. *	25.0	620. *	15.5	171.0	675.8	580.0	16237.5
OBP		280. *	12.0	620. *	15.5	141.5	588.9	580.0	11102.0

Fig.7 STIFFENER SELECTION INFORMATION



CAPACITIES;

20'L	CONTAINERS;	ON HATCHES	342
		IN HOLDS	426
			768
40'L	CONTAINERS;	ON HATCHES	156
		IN HOLDS	54
			210

GENERAL PARTICULARS;

LENGTH = 160.00 M
BREADTH = 26.50 M
DEPTH = 15.70 M
DRAUGHT = 9.37 M

Fig.8 GENERAL ARRANGEMENT PREPARED USING GRAPHICS SCREEN

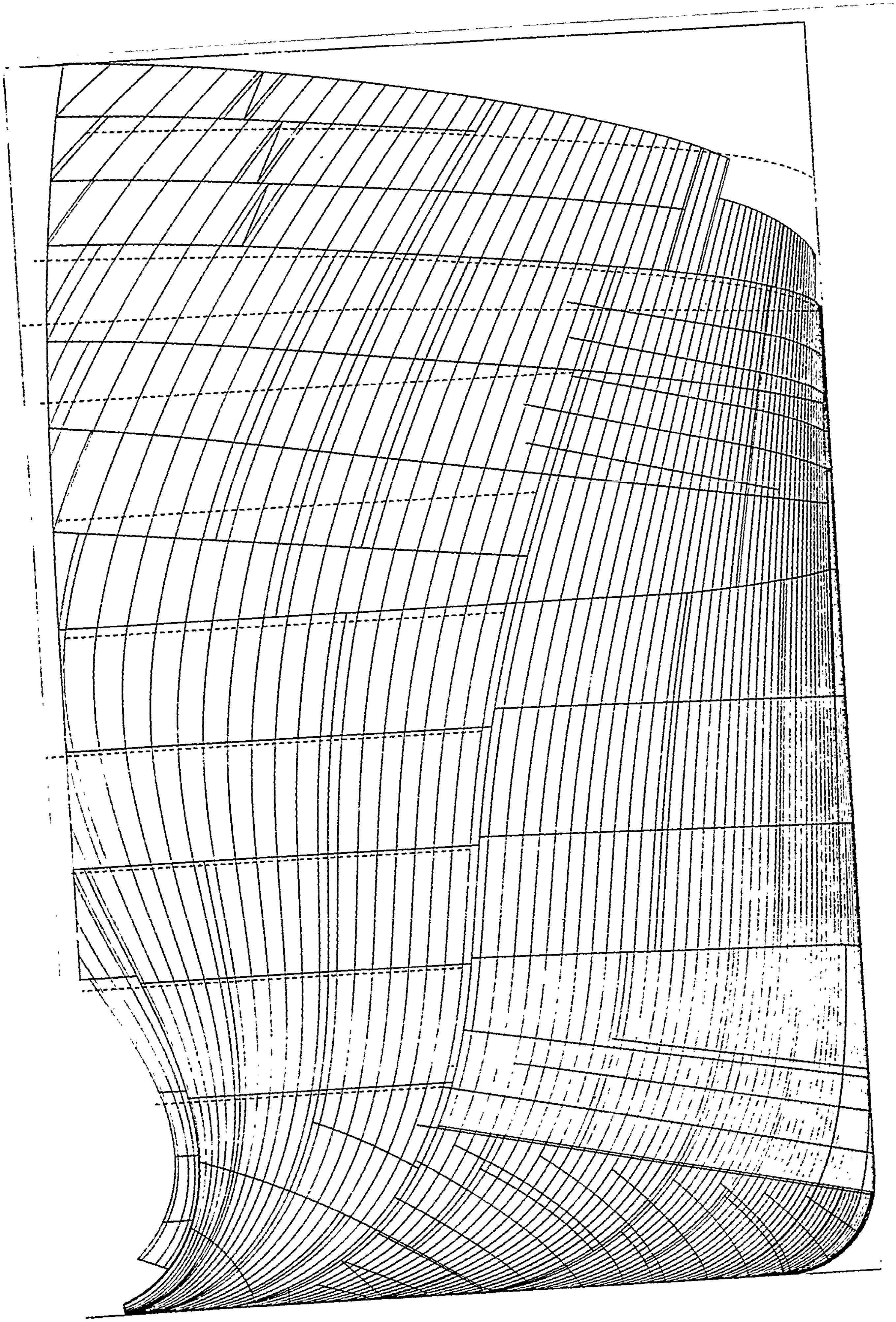


Fig.9 SHELL ARRANGEMENT LONGITUDINALS AND DECK-AT-SIDE LINES AS DEFINED IN THREE DIMENSIONS

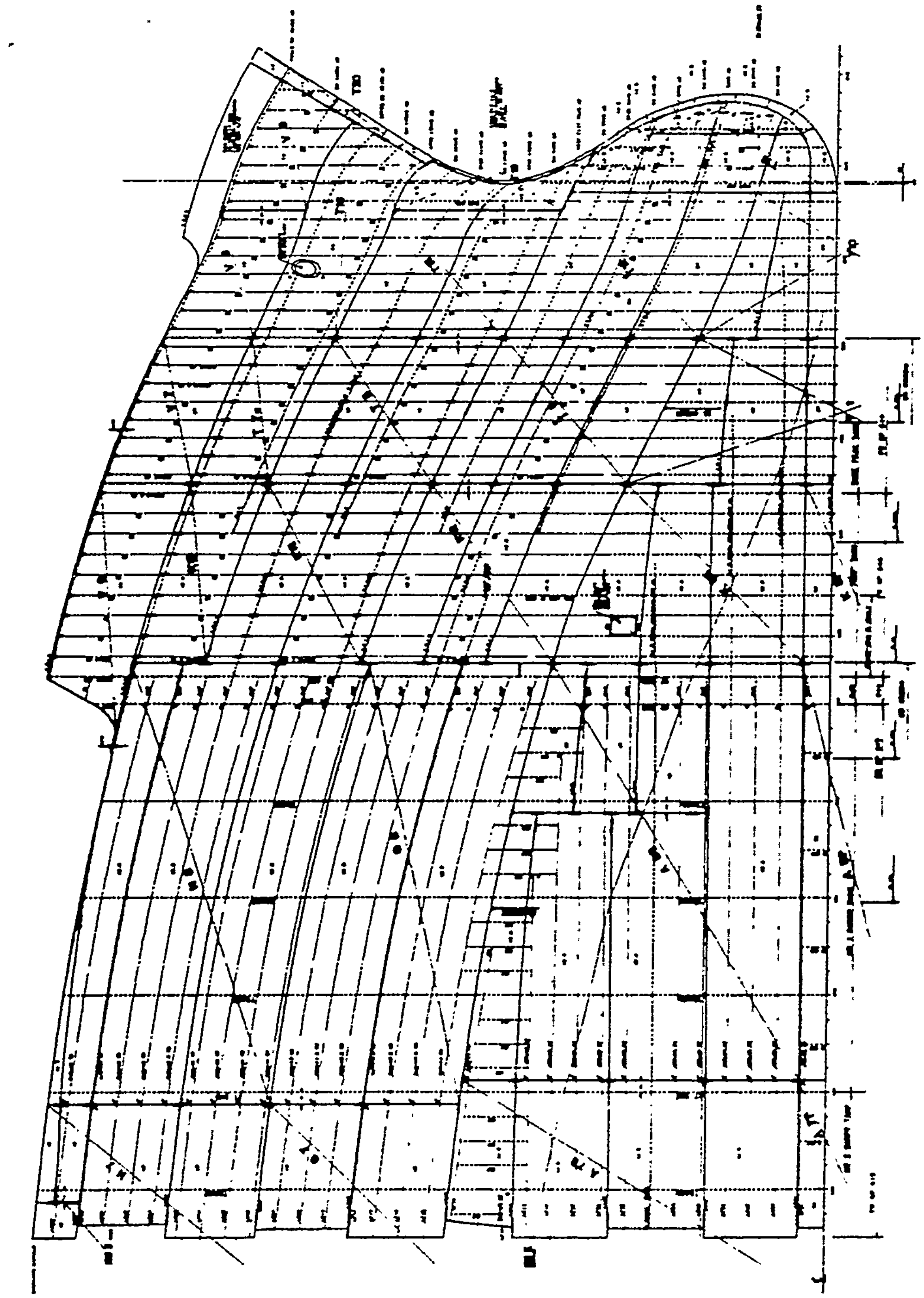


Fig.1 0 SHELL EXPANSION

OUTPUT FROM PROGRAM REQN DATE =25/08/82

GROUP =DRAW EMPNO =401A01 DRAWING =H/01-01 ORDER 01

PLATE REQUISITION DATA

UNIT	NOFF	I	MARK	THICK	GR	FINLEN	FINWID	REQLEN	REQWID	NITEMS	ITEM	NOFF
C02	2			12.5	1	12800	1500	12800	1500	1	403	1
C01	2			12.5	1	12800	1500	12825	1500	1	403	1
C02	2			18.0	1	12800	2530	12800	2530	1	404	1
C01	2			18.0	1	12800	2530	12825	2530	1	404	1
C02	2			12.5	1	12800	1519	12800	1519	1	405	1
C01	2			12.5	1	12800	1519	12825	1519	1	405	1
C02	2			11.5	1	12800	1519	12800	1519	1	104	1
C01	2			11.5	1	12800	1519	12825	1519	1	104	1
C01	1			13.0	1	7638	1500	7638	1500	3	101	1
											102	1
											109	1
C02	2			11.5	1	12800	1500	12800	1500	1	107	1
C01	2			11.5	1	12800	1500	12825	1500	1	107	1
C02	2			18.0	1	12800	2530	12800	2530	1	401	1
C01	2			18.0	1	12800	2530	12825	2530	1	401	1
C02	2			18.0	1	12800	2530	12800	2530	1	402	1
C01	2			18.0	1	12800	2530	12825	2530	1	402	1
C01	1			10.5	1	7161	3010	7161	3010	2	110	8
											111	8
C02	1			10.5	1	7161	3010	7161	3010	2	110	8
											111	8
C02	1	P		17.5	1	12800	1800	12800	1800	1	501	1
C01	1	P		17.5	1	12800	1800	12825	1800	1	501	1

OUTPUT FROM PROGRAM REQN DATE =25/08/82

GROUP =DRAW EMPNO =401A01 DRAWING =H/01-01 ORDER 01

STIFFENER ITEM REQUISITION DATA

UNIT	ITEM	NOFF	I	TYPE	GRADE	SCANTLINGS				FINLEN	REQLEN
C01	607	16		OB	1	180	8	0	0	1700	1700
C02	607	16		OB	1	180	8	0	0	1700	1700
C02	610	16		FB	1	150	12	0	0	1420	1420
C01	610	16		FB	1	150	12	0	0	1420	1420
C02	602	2		OB	1	300	12	0	0	12800	12800
C02	601	2		OB	1	300	12	0	0	12800	12800
C02	603	2		OB	1	300	12	0	0	12800	12800
C02	606	2		OB	1	300	12	0	0	12800	12800
C02	605	2		OB	1	300	12	0	0	12800	12800
C02	604	2		OB	1	300	12	0	0	12800	12800
C01	602	2		OB	1	300	12	0	0	12800	12825
C01	601	2		OB	1	300	12	0	0	12800	12825
C01	603	2		OB	1	300	12	0	0	12800	12825
C01	606	2		OB	1	300	12	0	0	12800	12825
C01	605	2		OB	1	300	12	0	0	12800	12825
C01	604	2		OB	1	300	12	0	0	12800	12825
C01	609	36		FB	1	150	12	0	0	1020	1020
C02	609	30		FB	1	150	12	0	0	1020	1020
C02	608	6		FB	1	150	12	0	0	1021	1021

Fig.11 STEEL REQUISITION LIST

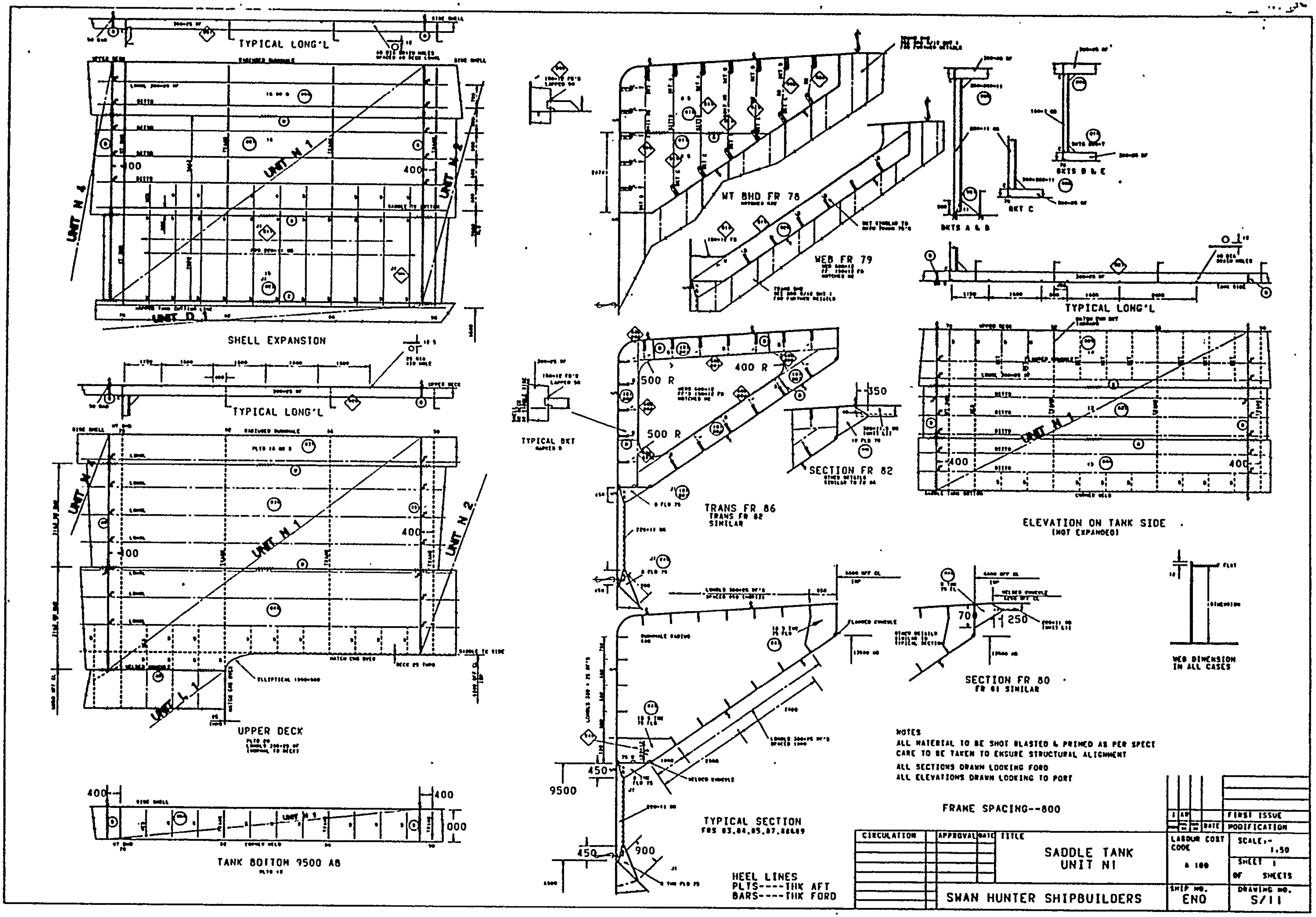


Fig.12 STEEL PRODUCTION DRAWING FOR SADDLE TANK UNIT

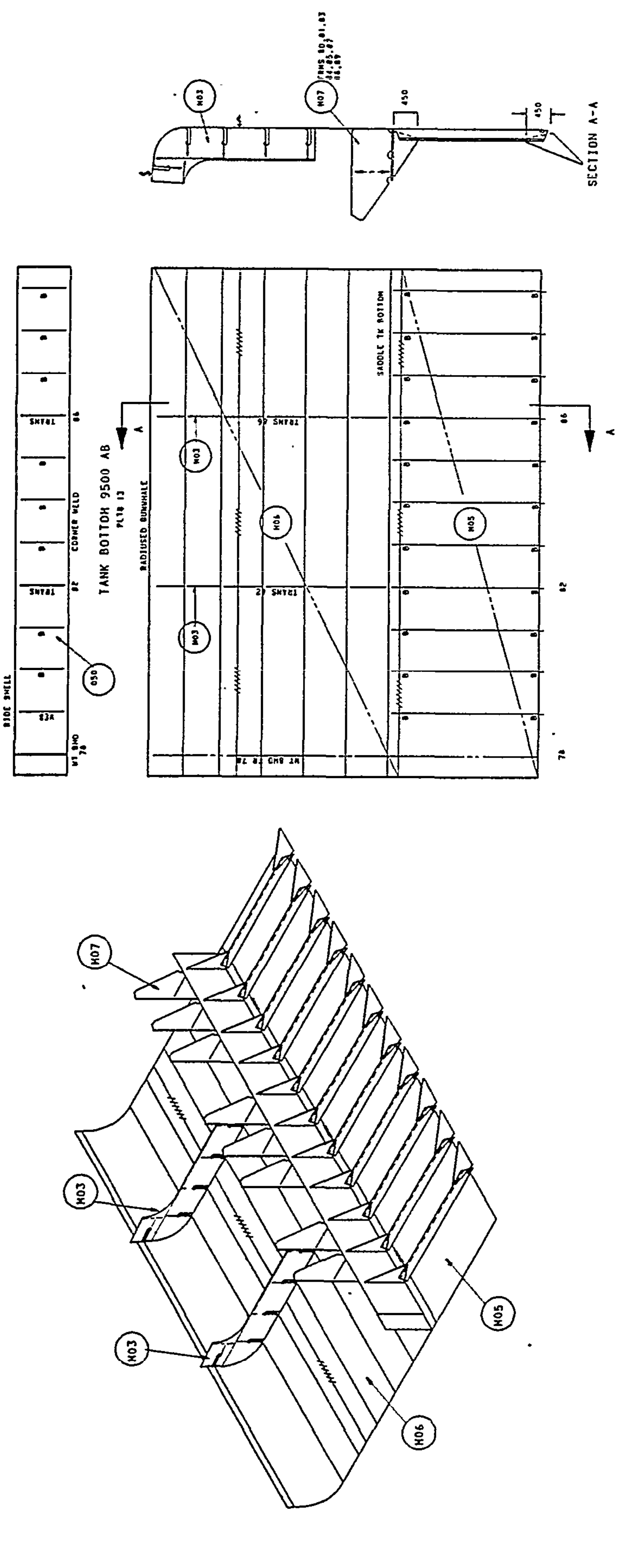


Fig.13 EXAMPLES OF WORKSTATION DRAWINGS

Fig.14 TYPICAL WORKSTATION PARTS LIST

WORKSTATION INFORMATION

UNIT : N01

SUB ASSEMBLY S03 1P 1S

WORKSTATION : SUB ASSEMBLY SHOP

COMPONENTS	NO.	THK	SIZE	TYPE	GRADE	WEIGHT	J'NT LENGTH
M06	1					9.276	
M05	1					14.115	9.60
N01 401 002	1	13			1	0.980	9.60
M07	8					1.357	12.40
M03	2					0.678	13.20

TOTAL WEIGHT = 36.58 TONNES

TOTAL J.L. = 44.80 METRES

NOTCHES

1ST CHARACTER N							5TH CHARACTER					
							BASIC	LUG N.R.S.	LUG R.S.	LUG 2.S	PART. COLLAR	FULL COLLAR
2ND CHAR		3RD CHAR		4TH CHAR			A	B	C	D	E	F
SLACK	S		1	PLAIN		A						
				WITH SEAM		B						
				WITH COIL		C						
CONN'D DIRECTLY	C	FULL BACK WELDED	1	PLAIN		A						
				WITH SEAM		B						
				WITH COIL		C						
		PART BACK WELDED	2	PLAIN		A						
				WITH SEAM		B						
				WITH COIL		C						
		WITH LAPPED STIFFR	3	PLAIN		A						
				WITH SEAM		B						
		W.BOTH SIDES	4			A						
TIGHT	T		1			A						
SLACK	S		6			A						
CONN'D DIRECTLY	C	PART BACK WELDED	7			A						

N.R.S.=NON REF.SIDE R.S.=REF.SIDE 2.S.=2 SIDES

Fig.15 STANDARD NOTCHES WITH THEIR ASSOCIATED CODES

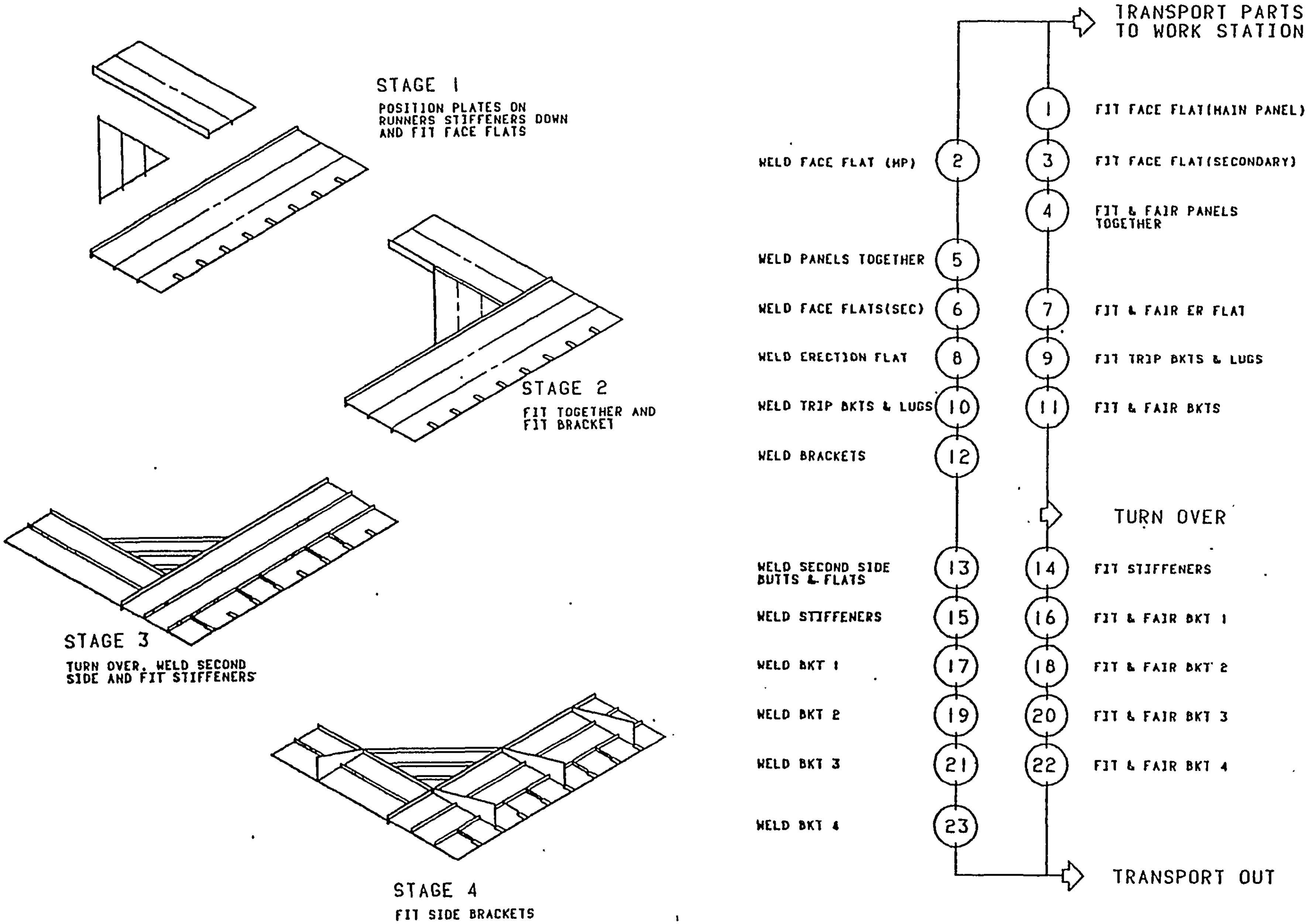
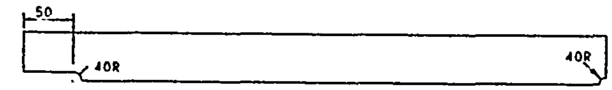


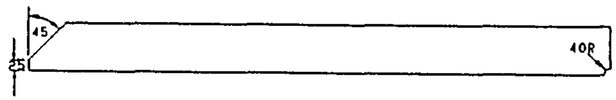
Fig.16 ASSEMBLY SEQUENCE AND PREFERRED PROCESS FLOW CHART

STIFFENER CARD

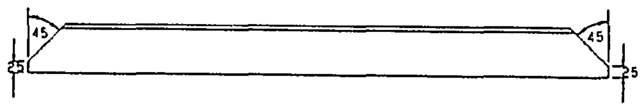
* DENOTES DRAWN FOR PORT OR STARBOARD



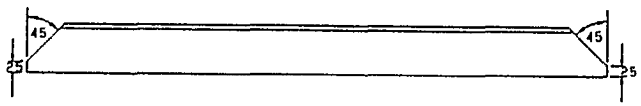
PART NUMBER	LENGTH	Nº P	Nº S	SCANTLING
N01/602/004	350	- 20	- 20	150*12/FB



PART NUMBER	LENGTH	Nº P	Nº S	SCANTLING
N01/602/002	729	- 1	- 1	150*12/FB



PART NUMBER	LENGTH	Nº P	Nº S	SCANTLING
N01/602/003'	8021	- 1	- 1	150*12/FB
N01/602/006	6020	3	3	150*12/FB
N01/602/007	6617	3	3	150*12/FB
N01/602/005	4448	3	3	150*12/FB



PART NUMBER	LENGTH	Nº P	Nº S	SCANTLING
N01/602/008	536	- 3	- 3	150*12/FB
N01/602/009	519	3	3	150*12/FB
N01/603/001	649	9	9	100*12/FB

Figure 3.	SHIP Nº	END	DRG TITLE:- UNIT. N01 STIFF CARD/3
	DATE	18/08/81	
	DRN BY:-	MJH	

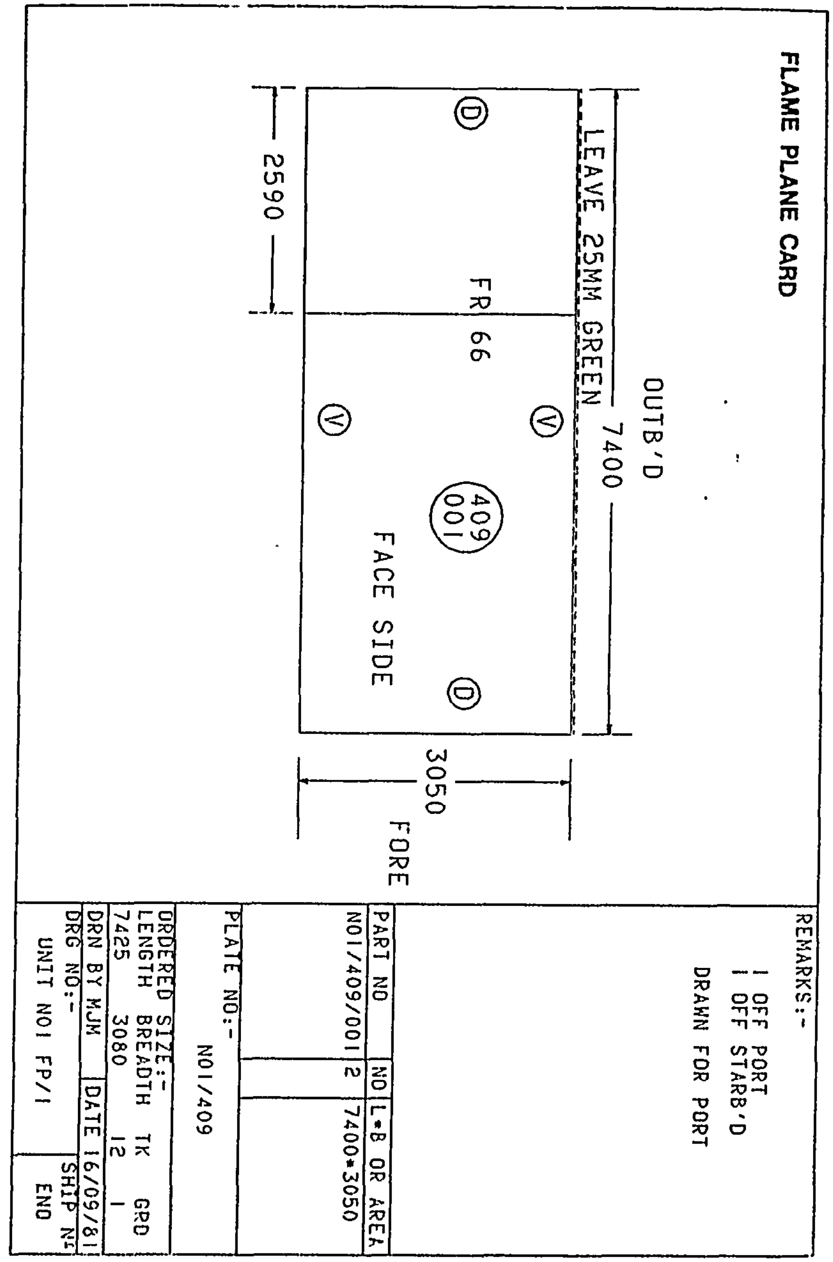


Fig.17 FLAME PLANE CARD AND STIFFENER PREPARATION INFORMATION

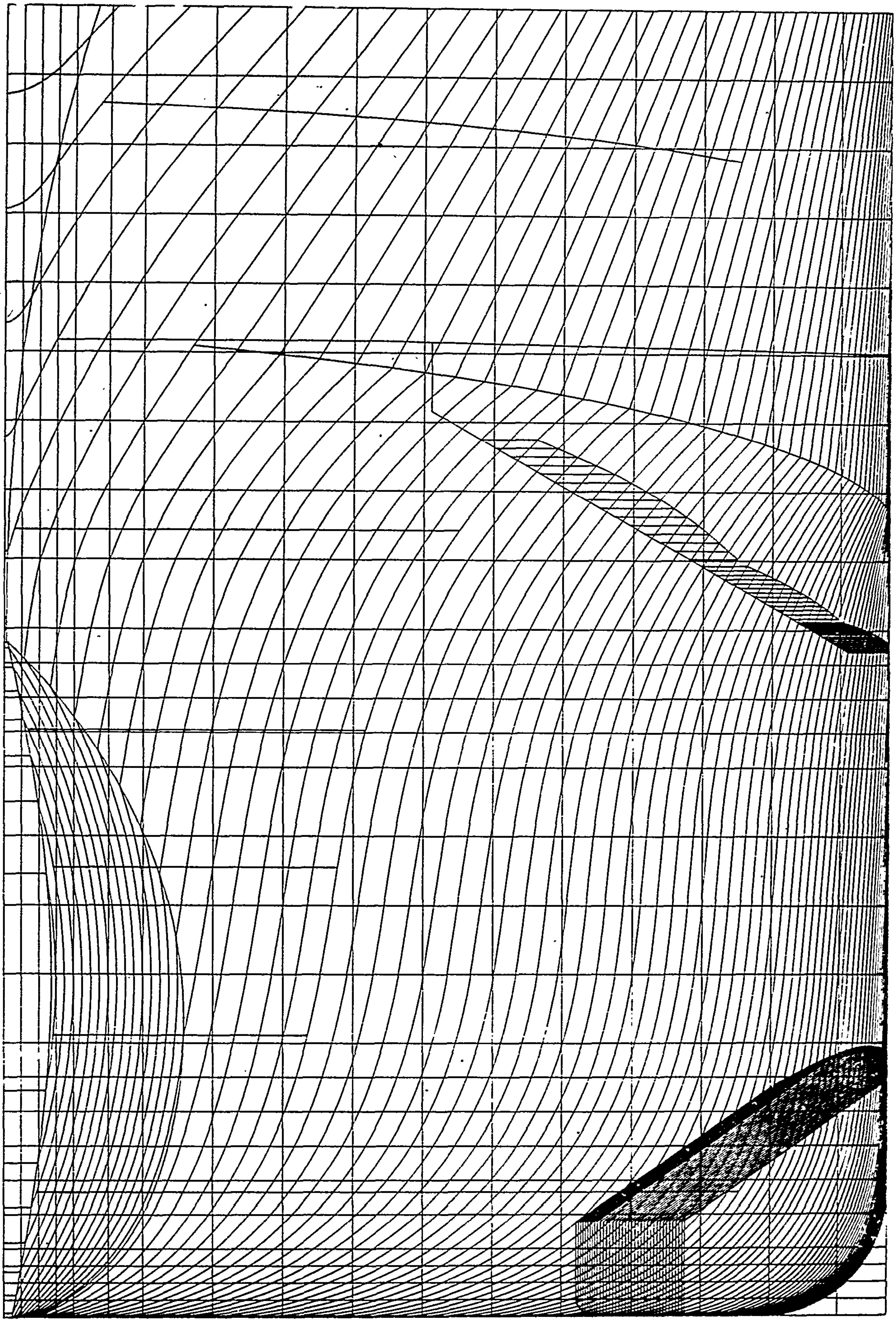


Fig.18 BRITFAIR - EXAMPLE OF BOW ENGINEERED FOR PRODUCTION

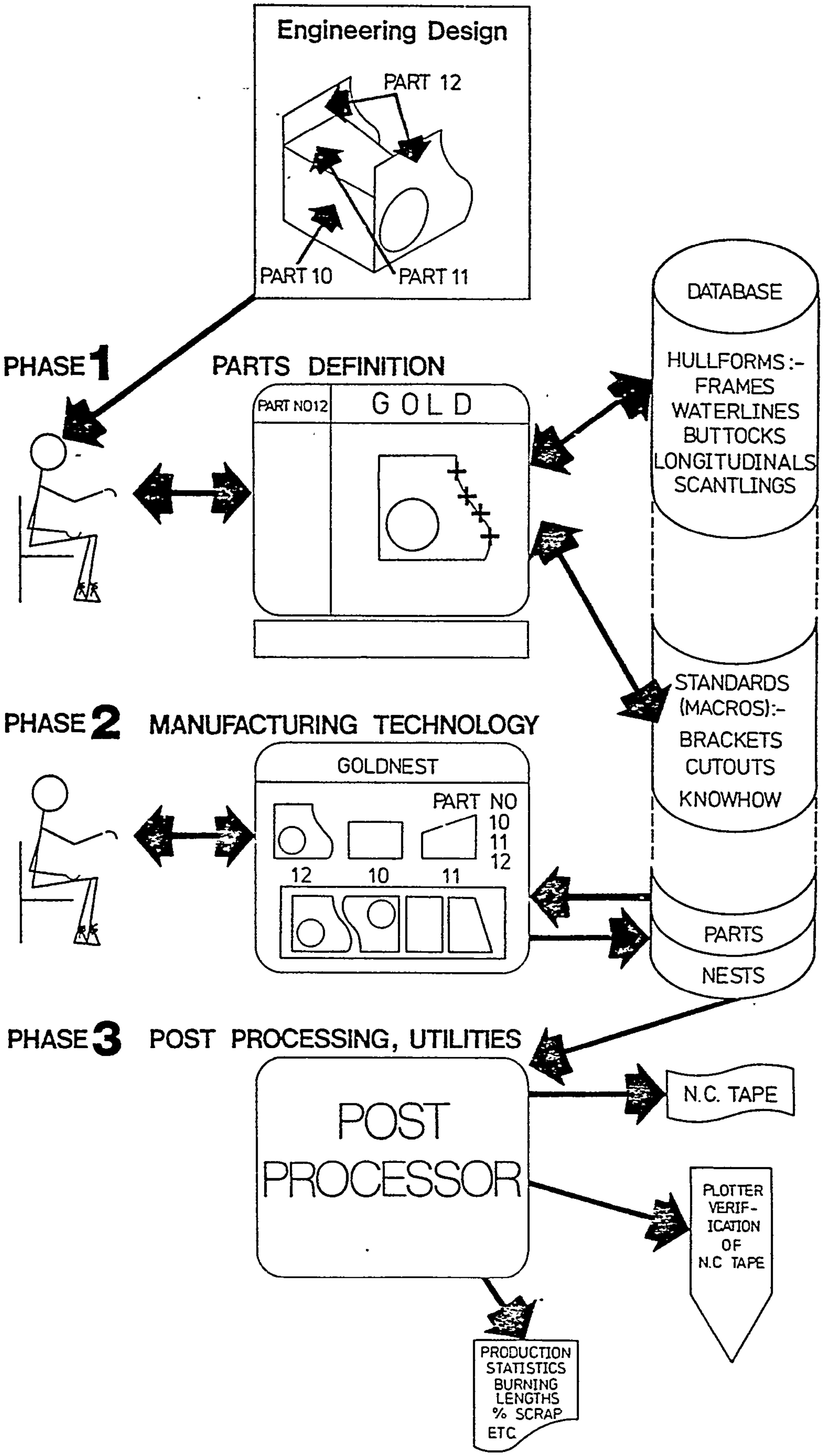


Fig.1 9 INFORMATION FLOW THROUGH GOLD

APPLICATIONS OF COMPUTER-AIDED
ENGINEERING TO SHIP SYSTEMS
AND STRUCTURES

James M. Reed
Principal Engineer
Westinghouse Electric Corp.

Mr. Reed has 20 years Westinghouse experience in Naval Nuclear and Commercial Nuclear Design Engineering and Management. He has been involved in Computer Aided Design since 1976, focusing on Mechanical Engineering Design Applications. Experience includes 7 years as lead engineer for design of Naval Nuclear Canned Motor Pumps for CVN 68. Recent commercial nuclear experience includes Manager of Nuclear Equipment engineering groups for primary equipment supports and auxiliary thermal equipment.

Mr. Reed received his B.S. and M.S. degrees in Mechanical Engineering from the University of Pittsburgh.

Dr. Kenneth F. Cooper
Manager Computer Aided Engineering
Westinghouse Electric Corp.

Dr. Cooper has 20 years experience in system transient performance analysis, system modeling, control and protection system design and analysis, control and protection system equipment design, mechanical equipment design and computer systems application. In his current position as Manager of Computer Aided Engineering for the Westinghouse Nuclear Technology Division he is responsible for the development of computer aided techniques associated with the automation of the NTD engineering process, the development of computerized physical plan modeling and design verification technique, the application of computerized plant modeling and design verification, and power plant development.

Dr. Cooper holds the following degrees:

BS - Electrical Engineering - University of Pittsburgh
MS - Automatic Control Systems - Rensselaer Polytechnic Institute
PHD- Automatic Control Systems - University of Pittsburgh

Dr. Thomas C. Esselman
Manager Structural Mechanics
Westinghouse Electric Corp.

Dr. Esselman has 10 years experience in seismic and pipe ruture analysis, thermal hydraulic design, performance testing, structural criteria and development, regulatory issues, and equipment design and procurement. He is currently Manager of Structural Mechanics for the Westinghouse Nuclear Technology Division responsible for piping analysis, piping support design, structural engineering, and structural/mechanical development for commercial nuclear power plants.

Dr. Esselman holds the following degrees:

BSME - Mechanical - Case Institute of Technology
MS - Engineering Mechanics - Case Western Reserve
MBA - Business - University of Pittsburgh
PHD - Engineering Mechanics - Case Western Reserve

Applications of Computer-Aided Engineering to Ship Systems and Structures

ABSTRACT

The Westinghouse Electric Corporation computer-based capabilities in geometric modeling and piping/support design and analysis were developed for the design and construction of nuclear power plants. Since the requirements for the design and analyses of piping systems and compartments for naval vessels are similar to those for nuclear power plants, these capabilities have many potential applications to ship systems and structures.

Westinghouse computer-aided engineering systems can be used at naval shipyards through fully equipped Structural Analysis Mobile Units, electronically linked to mainframe computers in Pittsburgh, Pennsylvania.

To illustrate the potential application of Westinghouse computer-aided engineering (CAE) capabilities, an example of an auxiliary machinery compartment on board the USS Nimitz (CVN 68) was modeled and selectively analyzed.

INTRODUCTION

The Westinghouse computer-aided engineering system is an integrated design approach which maintains a computer-based description of the physical design and ties in the piping and support system design and analysis. This results in a design that can be optimized to meet specified criteria (for instance, minimum weight) and provide a “living” record that can be used repeatedly for maintenance and modification.

Since the geometric representation is stored in the computer, access and communication activities are rapid and modifications to the design description can be made easily, not only during construction but throughout ship life.

COMPUTER-AIDED ENGINEERING CAPABILITIES

Nestinghouse has been a leader in the development of nuclear power plants for over 25 years through research, design engineering, manufacturing, and construction. The support of this evolving business has required the development of advanced engileering tools. The currently available Westinghouse CAE capabilities include plant layout, piping design, piping analysis, support/hanger design, and drawing preparation.

The considerations involved with the design and analysis of piping and support systems and space management in nuclear power plants are very similar to those required for the design and construction of naval ships. The currently available CAE capabilities at Westinghouse are applicable to the naval ship design and construction program.

A major concern with the transportability of the nuclear-developed technology and techniques may be the size and complexity of the design project. As a point of reference, a typical 1000-megawatt electric nuclear power plant contains the following quantities of equipment:

- 260,000 feet of piping
- 112,000 feet of electrical raceways
- 32,000 feet of HVAC ducts
- 30,000 structural supports
- 5,000 valves
- Hundreds of tanks, heat exchangers, and pumps

The application of the Westinghouse CAE capabilities is illustrated in figure 1, which shows that there are three distinct but integrated functions. These functions are separable, but the maximum benefits are realized when all functions are performed using computer automation.

Westinghouse also has fully equipped Structural Analysis Mobile Units (SAMUs), electronically linked to mainframe computers in Pittsburgh, Pennsylvania; these can be used for computer-aided engineering at remote sites.

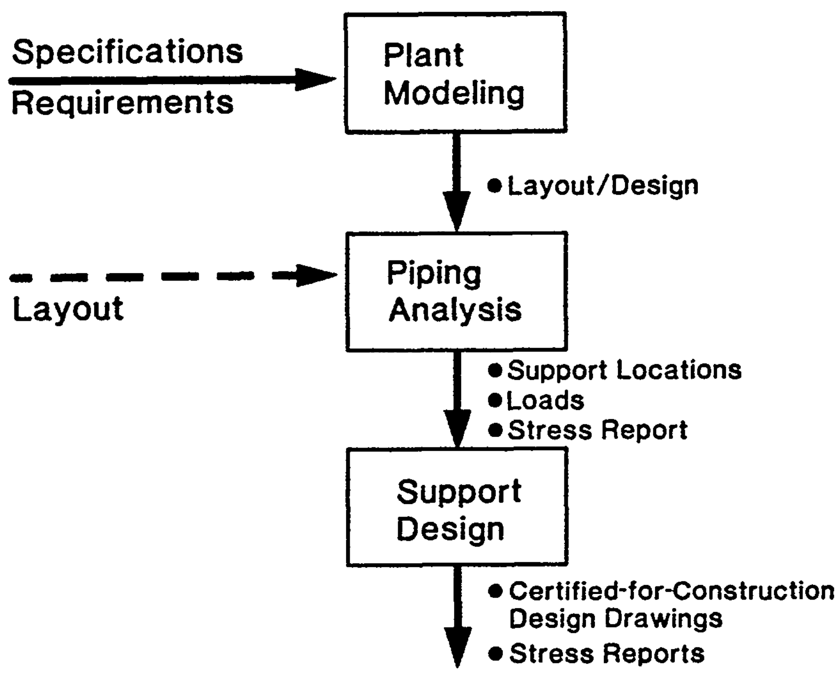


Figure 1.
Design/Qualification Process

PLANT MODELING

One of the major requirements during the design and construction of a nuclear power plant is to ensure that the equipment and piping layout minimizes congestion and interferences. To address this problem, Westinghouse utilizes a computer system with a graphics interface to create a visual, three-dimensional graphic representation of plant structure, including all piping and equipment. The "intelligent" data base of the plant thus created is used to optimize the plant design.

In addition to providing this visualization of the plant, the constructed data base can be used for space management, structural analysis, design verification, and automatic generation of data (such as bills of material) necessary for management of the design and construction of the plant.

The data base for the plant model is constructed using a layering technique. This allows many people to work on the construction of the data base at the same time, and also allows segmentation for investigating subsection relationships. The layers of the data base are combined to generate the total plant composite model. This data base relationship is indicated in figure 2.

The following advantages are realized from computerized plant modeling:

- **Design standardization** — Design standardization is accomplished through the use of standard components which are predefined in computer libraries.
- **Interference resolution** — Interferences are identified by automatic computer searches and resolved by visual observation of the space available for modifications.
- **Reduction of construction costs associated with delays** — The quality of the engineering provided to construction using this tool is superior to that of conventional techniques and significantly reduces the number of construction problems. This in turn reduces costs.
- **Creation of a computerized plant data base** — This data base can be used to (1) generate required plant drawings, (2) interface directly with computerized analysis and design programs, and (3) facilitate future modifications to the design.

Examples of computer-based modeling are given in figures 3 through 6. These figures show the use of the layering technique and the composite of a total compartment (in this case, cubicle 18) model. The system also has the capability to concentrate the visual presentation on any subsection of the model for detailed investigation of an area or volume. Figure 7 is an example of the type of data extract which can be obtained from the computer data base.

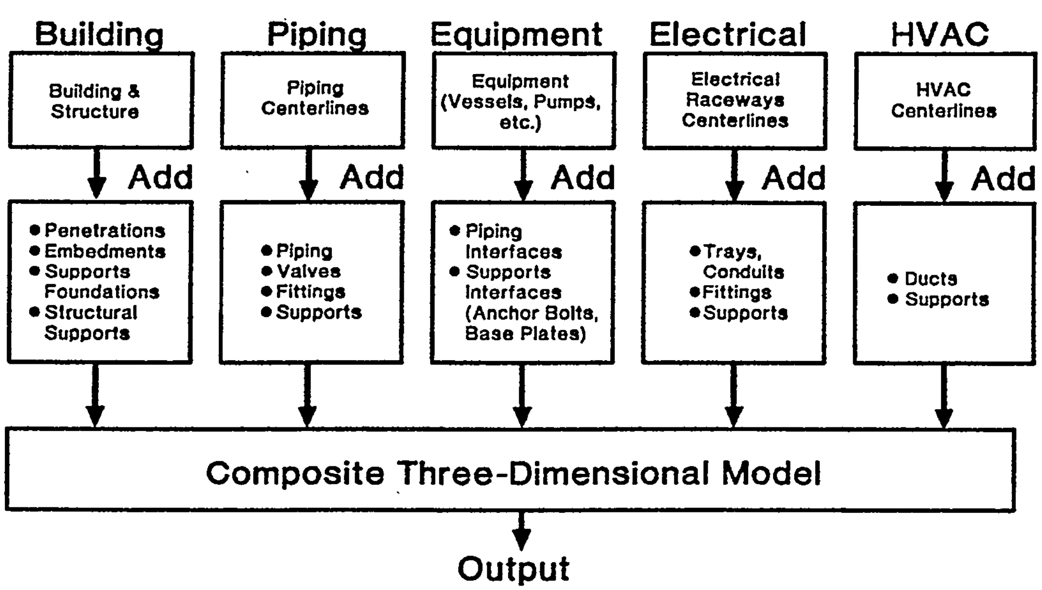


Figure 2.
Layer Technique for Generating Plant Model

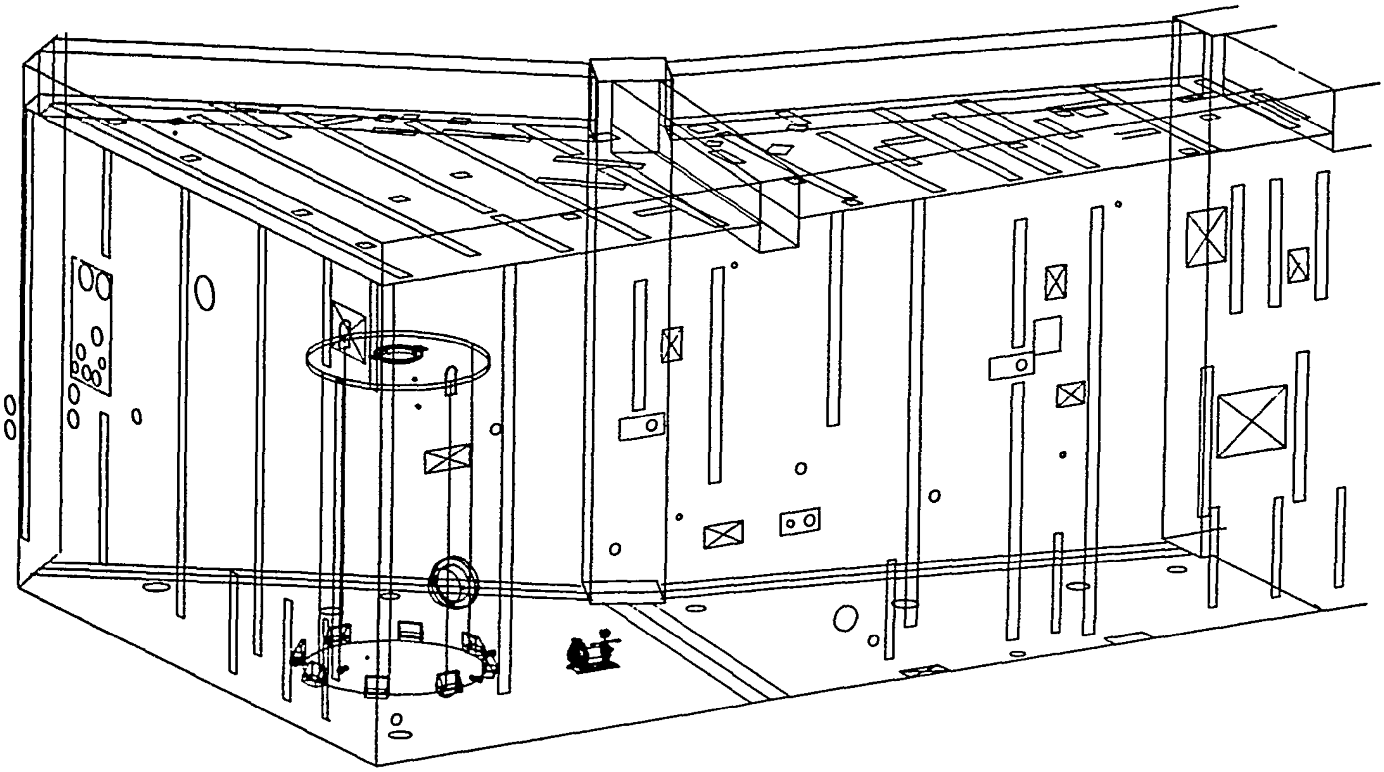


Figure 3.
Building, Structure, Penetrations, and Equipment

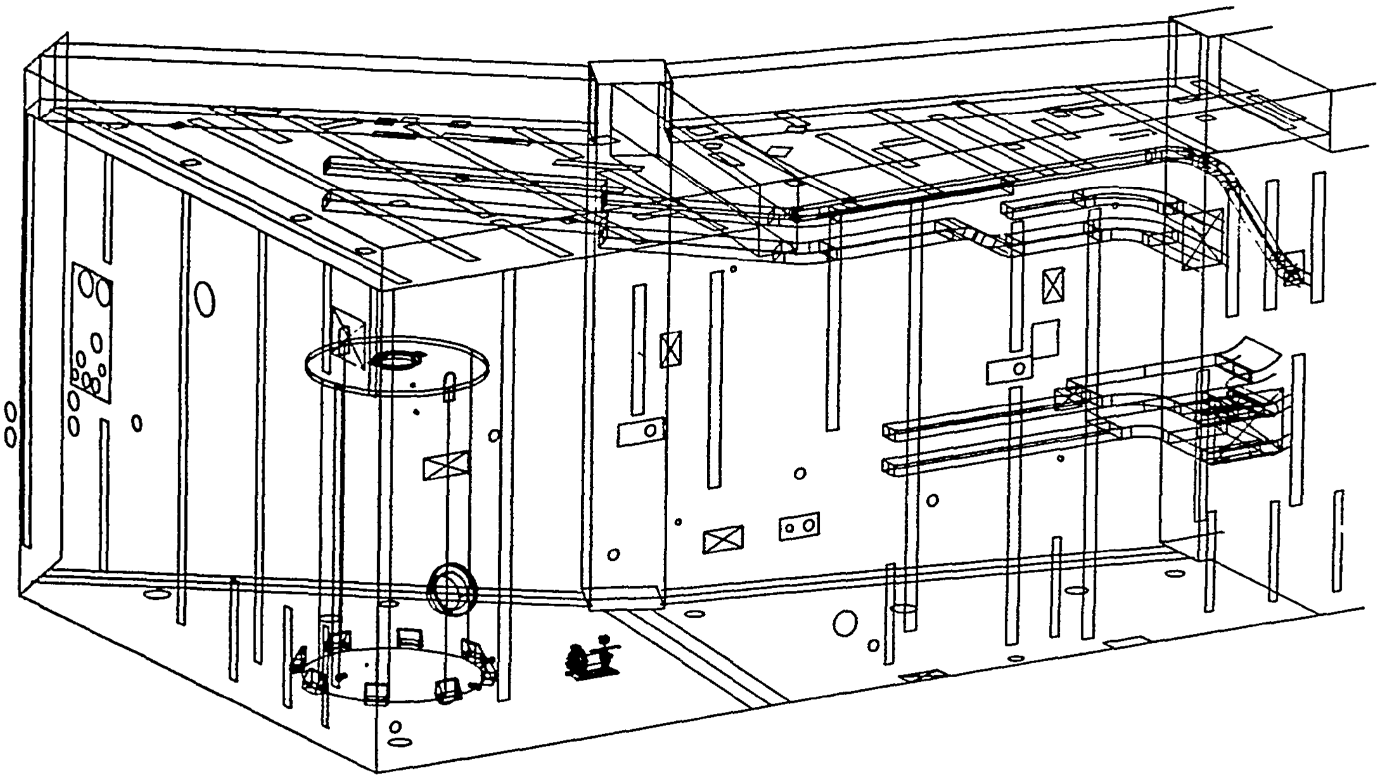


Figure 4.
Electrical Raceways

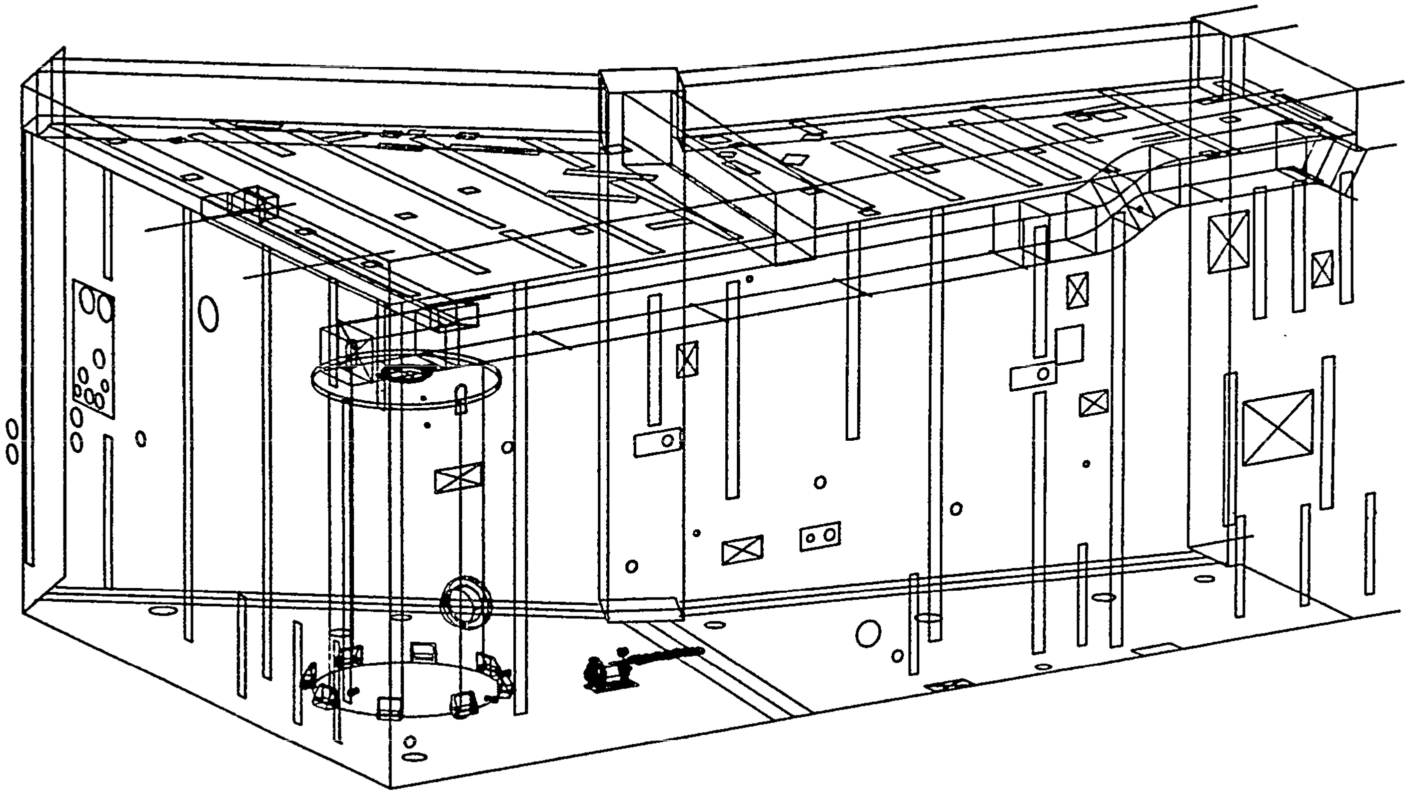


Figure 5.
Heating, Ventilating, and Airconditioning Ducts

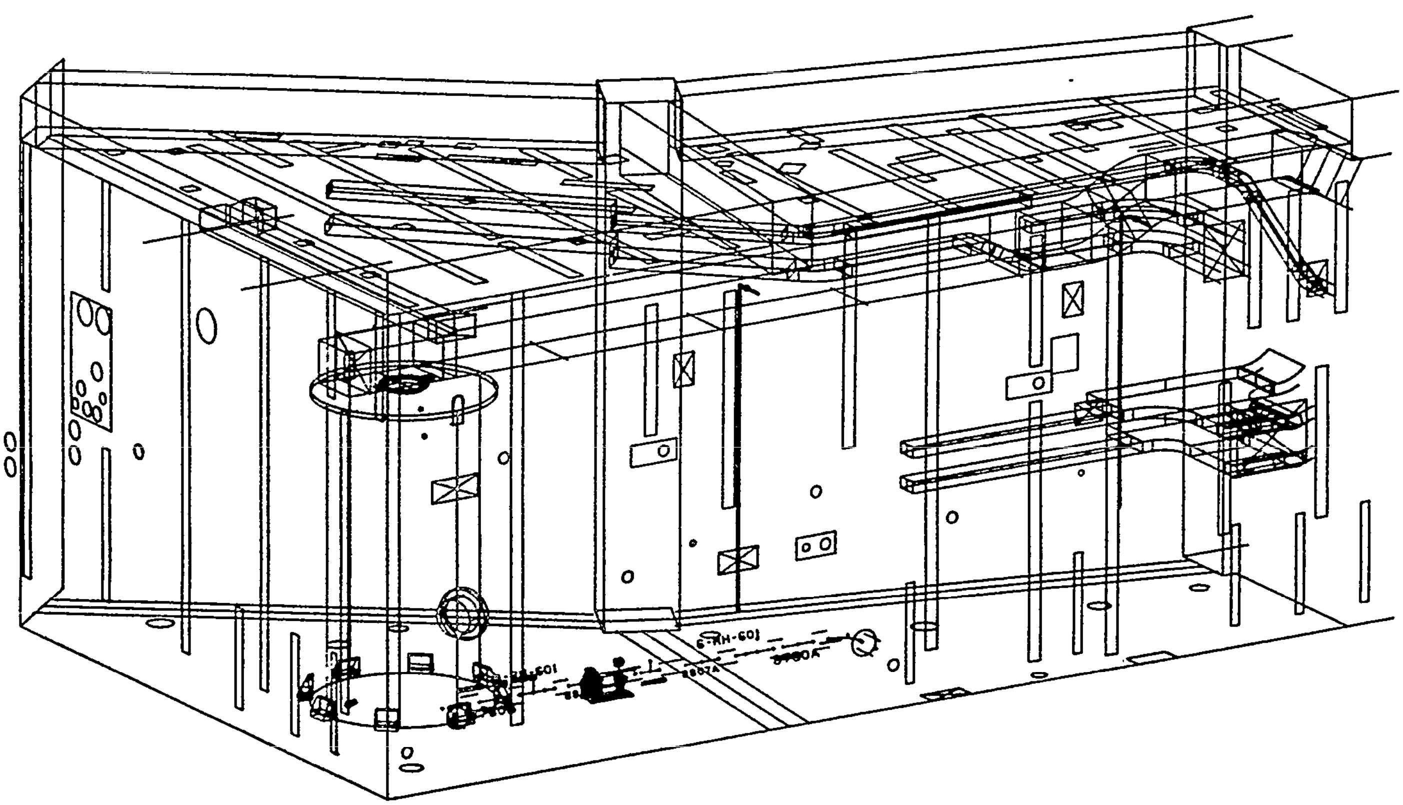


Figure 6.
Cubicle 18 (Piping and Supports Added)

A very important function performed by the plant modeling activity is space management in congested areas of the plant. This control is achieved by maintaining a computer data base of the physical design and incorporating and validating changes as they occur. Accurate computerized records of the design changes are created at the same time the model data base is updated. This configuration management prevents the unnecessary complexity which results when the various construction disciplines install their components in congested plant areas on a "first-come, first-served" basis.

LINE	FROM	TO	PIPE
10-SW-151	****************	****************	534.284

SPEC	COMP		STK#
10-151	PIPE:	11.000	PIPEPEAM40S-10
10-151	ESR9		ESR9WEAP40S-10
10-151	VALV		8G52QQ
10-151	HGR		TYPE.5A
10-151	PIPE:	6.750	PIPEPEAM40S-10
10-151	ELR9		ELR9WEAP40S-10
10-151	PIPE:	0.500	PIPEPEAM40S-08
10-151	RTEE		RTEEWEAP40S-1008
10-151	CRED		CREDWEAP40S-1008
8-151	HGR		TYPE.5A
8-151	PIPE:	17.931	PIPEPEAM40S-08
8-151	BEND:	31.420	PIPEPEAM40S-08
8-151	PIPE:	38.988	PIPEPEAM40S-08
8-151	BEND:	31.420	PIPEPEAM40S-08
8-151	HGR		TYPE.5A
8-151	HGR		TYPE.5A
8-151	HGR		TYPE.5A
8-151	PIPE:	130.638	PIPEPEAM40S-08
8-151	BEND:	22.939	PIPEPEAM40S-08
8-151	PIPE:	33.553	PIPEPEAM40S-08
8-151	BEND:	22.939	PIPEPEAM40S-08
8-151	HGR		TYPE.5A
8-151	PIPE:	42.206	PIPEPEAM40S-08
8-151	ELR9		ELR9WEAP40S-08
8-151	PIPE:	70.500	PIPEPEAM40S-08
10-151	CRED		CREDWEAP40S-1008
10-151	ESR9		ESR9WEAP40S-10
8-151	PIPE:	2.000	PIPEPEAM40S-08
8-151	ESR9		ESR9WEAP40S-08
8-151	PIPE:	38.500	PIPEPEAM40S-08
8-151	VALV		8BA74D
8-151	PIPE:	33.000	PIPEPEAM40S-08
8-151	CRED		CREDWEAP40S-1008
10-151	ESR9		ESR9WEAP40S-10

Figure 7.
Piping Bill of Material Using Piping Software

PIPING ANALYSIS

The interactive computer system developed for piping analysis has increased the quality of the analysis and the productivity associated with it over conventional techniques. Figure 8 shows the task flow for the piping analysis system.

The piping analysis system can obtain input definition data either from the plant modeling system or from piping drawings (for systems not designed using plant modeling). This input information is used to automatically generate a computer model for stress analysis using finite element analysis techniques. The generation of the plant model is accomplished through an interactive graphic system by means of a user-friendly manual system and taking advantage of computer libraries of incorporated parts and properties. The system automatically generates all stress and configuration documentation required for design documentation. and verification. The analysis code incorporates the applicable load combinations and allowable limits.

A complete, descriptive computer data base of the piping system being analyzed is generated by the interactive piping analysis program. When an acceptable (as defined by specified evaluation criteria) piping system design is obtained, the computer data base describing the piping system is used to generate an isometric drawing of the piping system, The data base is also used to extract tabular information such as pipe material, pipe size, support locations, and support types; these are placed on the isometric drawings. The program can specify the format for the drawings and automatically dimension and label the drawings. Figure 9 is an example of a piping system model on the interactive system, and figure 10 is an example of an isometric drawing generated by the system.

As an example of how the piping analysis system can yield simpler and more cost-effective designs, table 1 give the results of applying the piping analysis system to a particular line. The analysis of the line permitted a redesign which is simpler and less expensive than that produced by traditional, manual techniques.

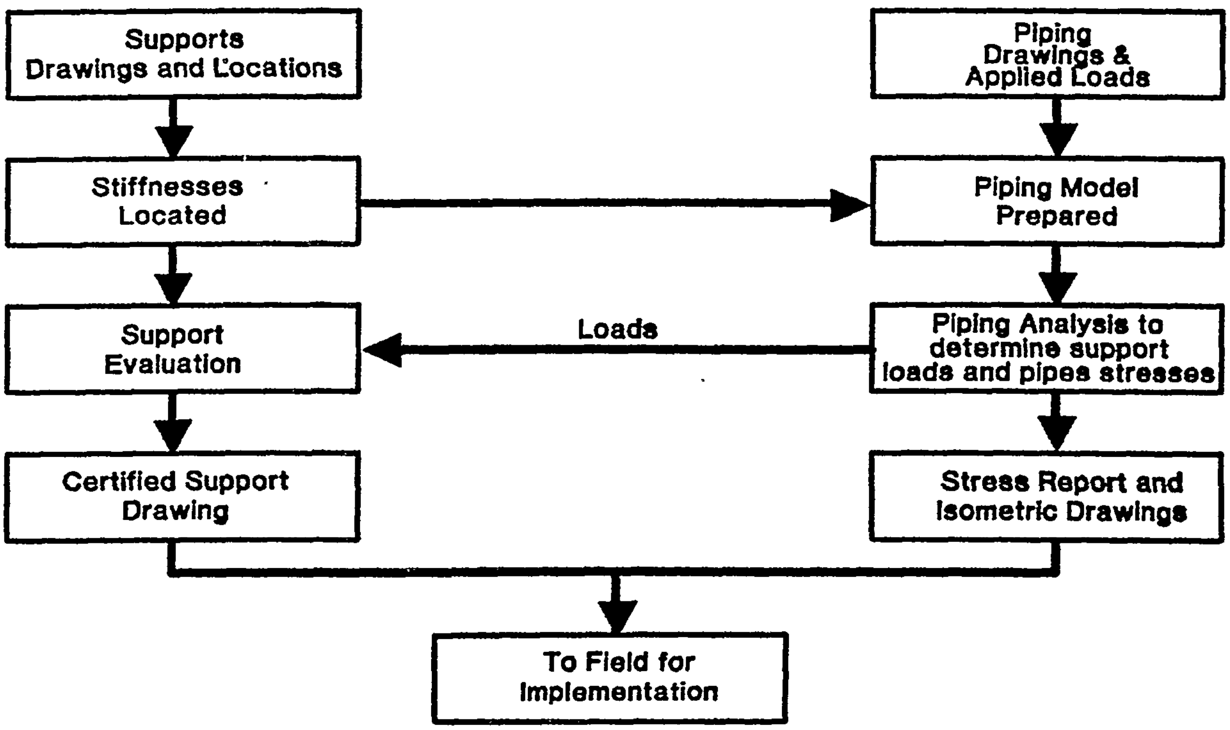


Figure 6.
Flow of Piping and Support System Evaluation

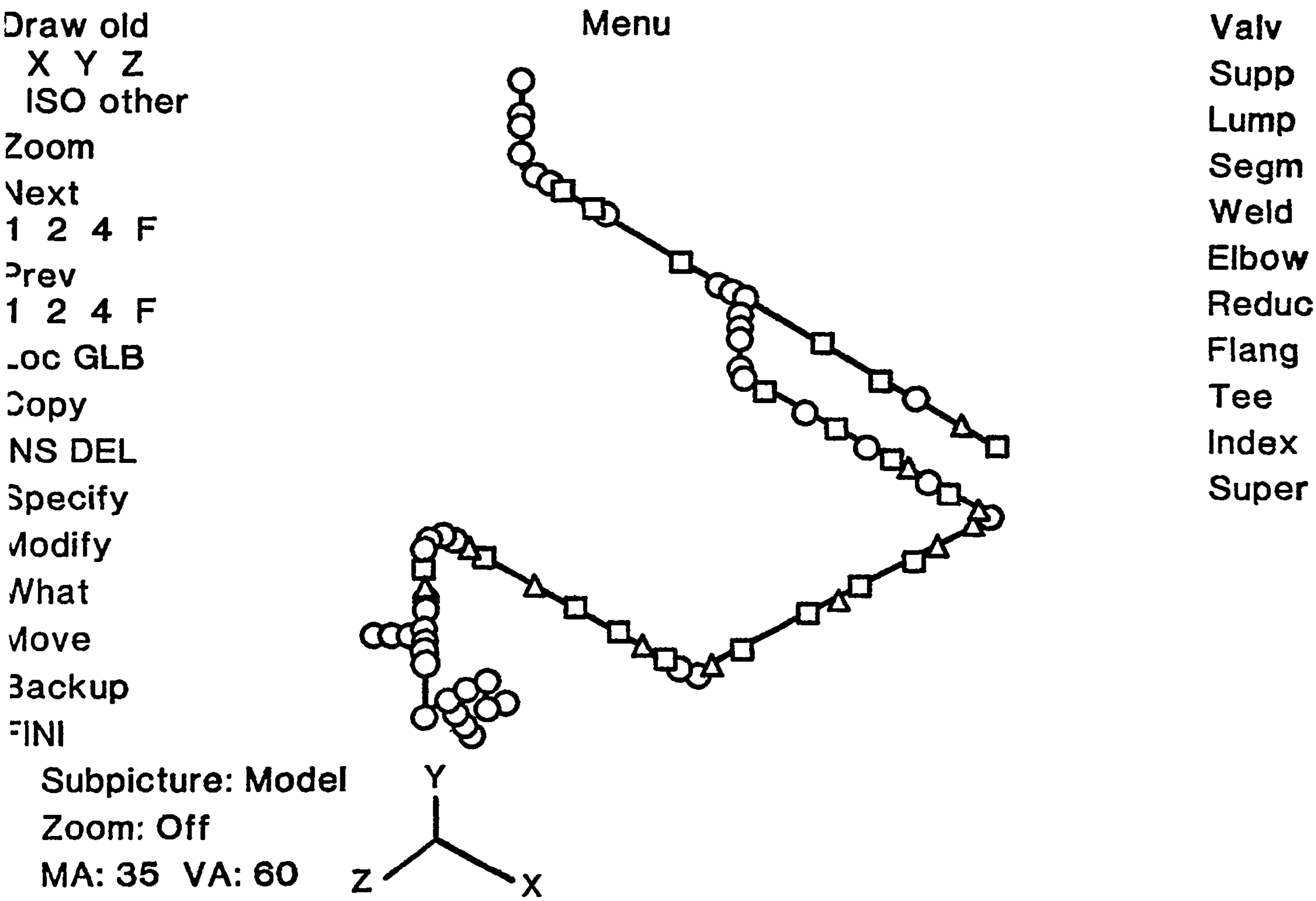


Figure 9.
System-Generated Piping System Model

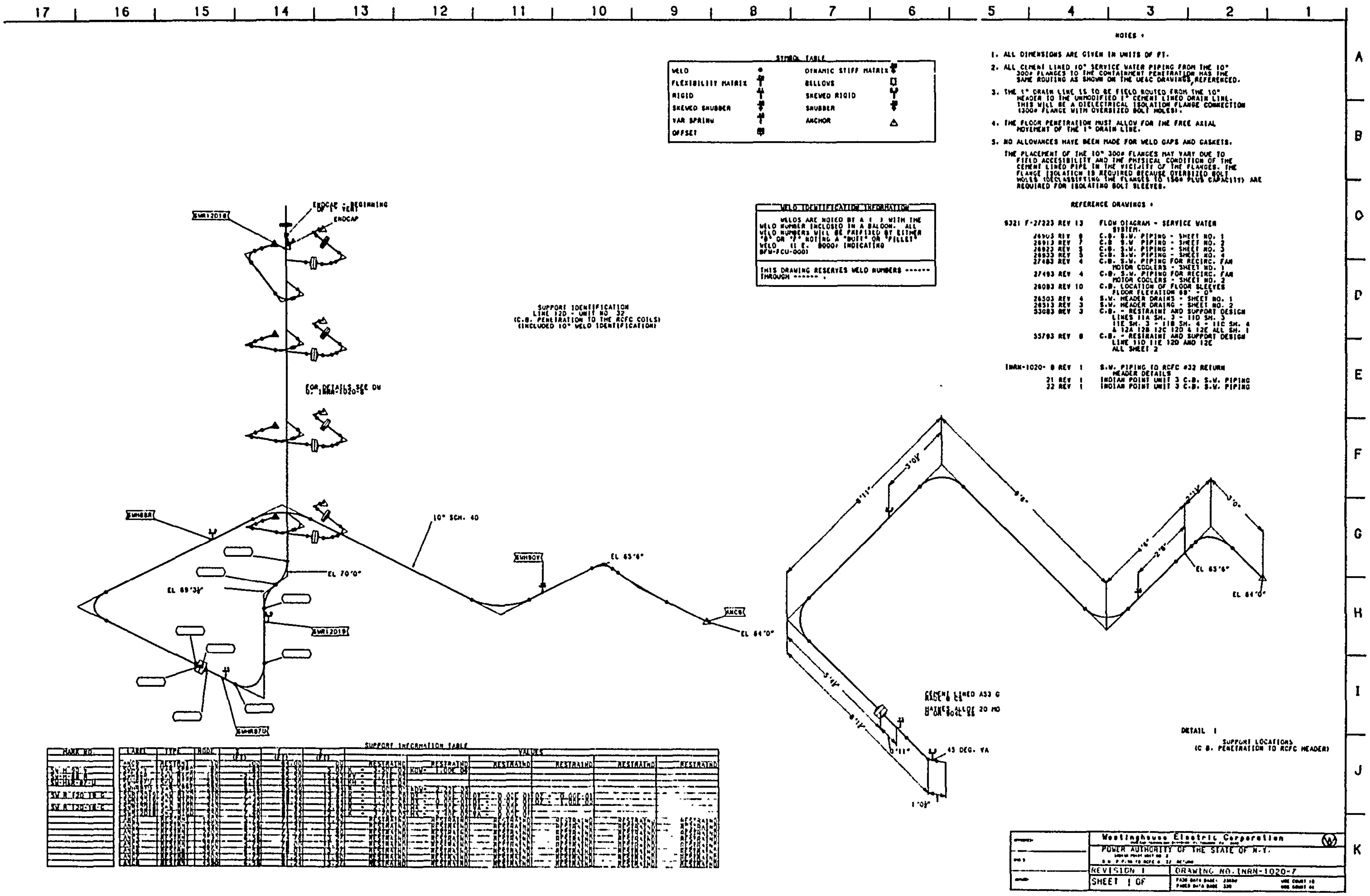


Figure 10.
System-Generated isometric Drawing

Table 1
Results of Redesign of Commercial Nuclear Plant Piping
(2-Inch Line, Approximately 80 Feet)

Original configuration	12 supports total (10 rigid, 2 VSH)
First-iteration configuration	7 supports total (6 rigid, 1 VSH)
Total weight reduction	656 pounds

SUPPORT DESIGN AND ANALYSIS

An interactive computer system similar to that developed and applied for piping systems is available for support design and analysis. This program establishes the support design; determines the support stiffnesses to be utilized by the piping analysis; evaluates the loads and the stresses in structural steel; utilizes and verifies the adequacy of standard component supports; evaluates base plates, wedge anchors, embedded plates, and anchor bolts; and determines snubber and variable spring settings.

As indicated above, the approach used in developing this program is the same as that utilized for the piping analysis program. It is an interactive graphics program which utilizes standardized data bases for materials, member properties, and components. Complete documentation, including tabular summaries and plots, is standard output from the system. The determined support stiffnesses are documented and automatically made available to the appropriate piping system analysis. The analysis associated with this system is performed on a minicomputer system.

Like the piping analysis program, the support design and analysis program utilizes the design and analysis data base to produce a detailed support drawing. The capability to format, define, and tabulate support data in the drawings is part of the drawing package incorporated in this system.

Figure 11 is an example of the support program interactive screen, and figure 12 is an example of a support drawing generated by the system.

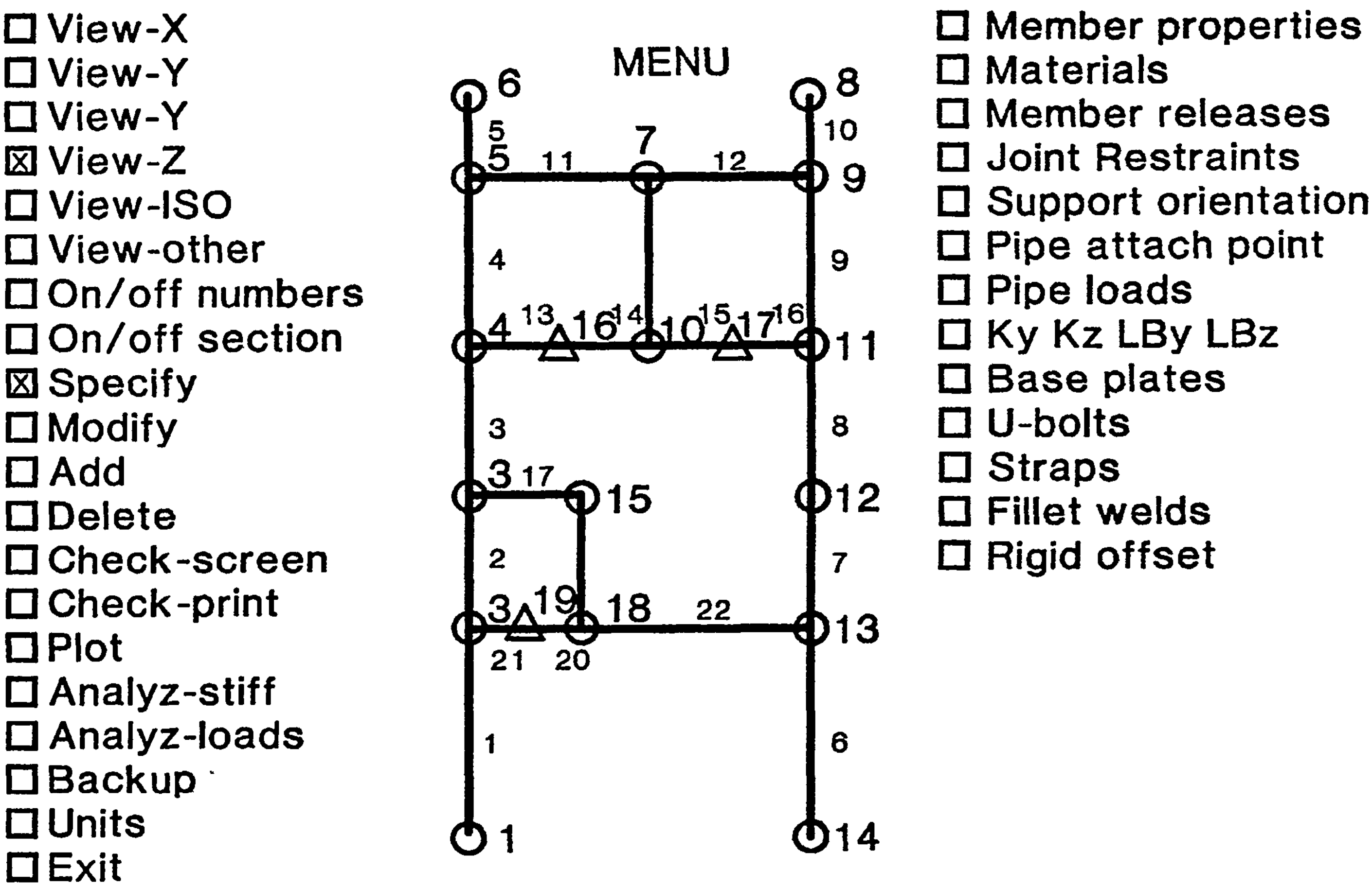


Figure 11.
System-Generated Support Program Screen

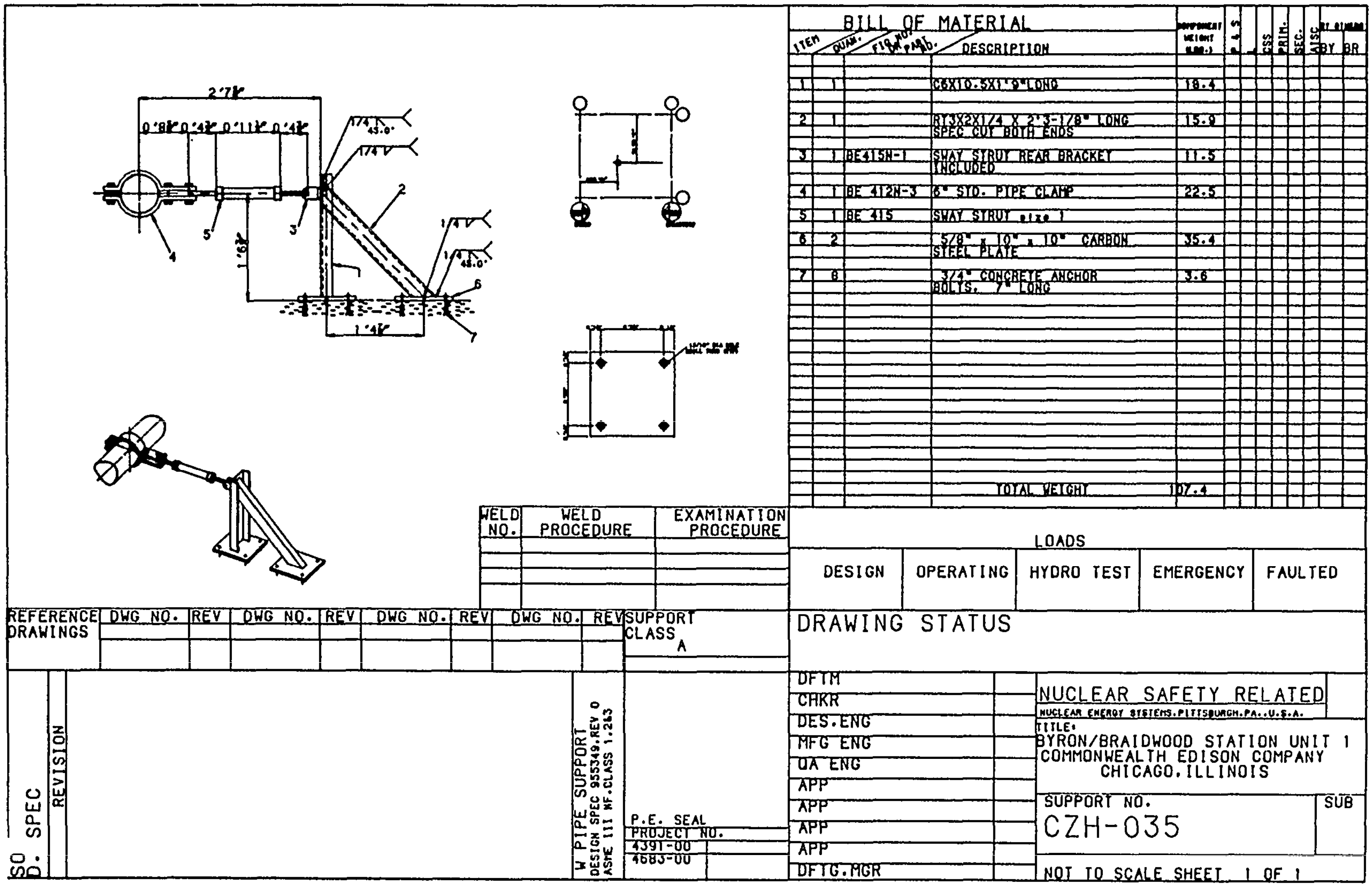


Figure 12.
System-Generated Support Drawing

SHIPBOARD APPLICATION

To demonstrate the applicability of the described programs to the design and construction of naval ships, the described system was applied to an auxiliary machinery compartment on the USS Nimitz. The area was modeled and selectively analyzed. The model included hull shape, compartment location, compartment structure, airconditioning units, saltwater pumps, chill water pumps, fire protection pumps, HVAC ducts, and the related piping and hangers. The data file necessary for analysis of the saltwater piping system was transmitted to the piping analysis system. Figure 13 is the plant model developed, and figure 14 is the piping system analyzed as shown on the piping system interactive graphics terminal. The results of the piping analysis are shown in table 2.

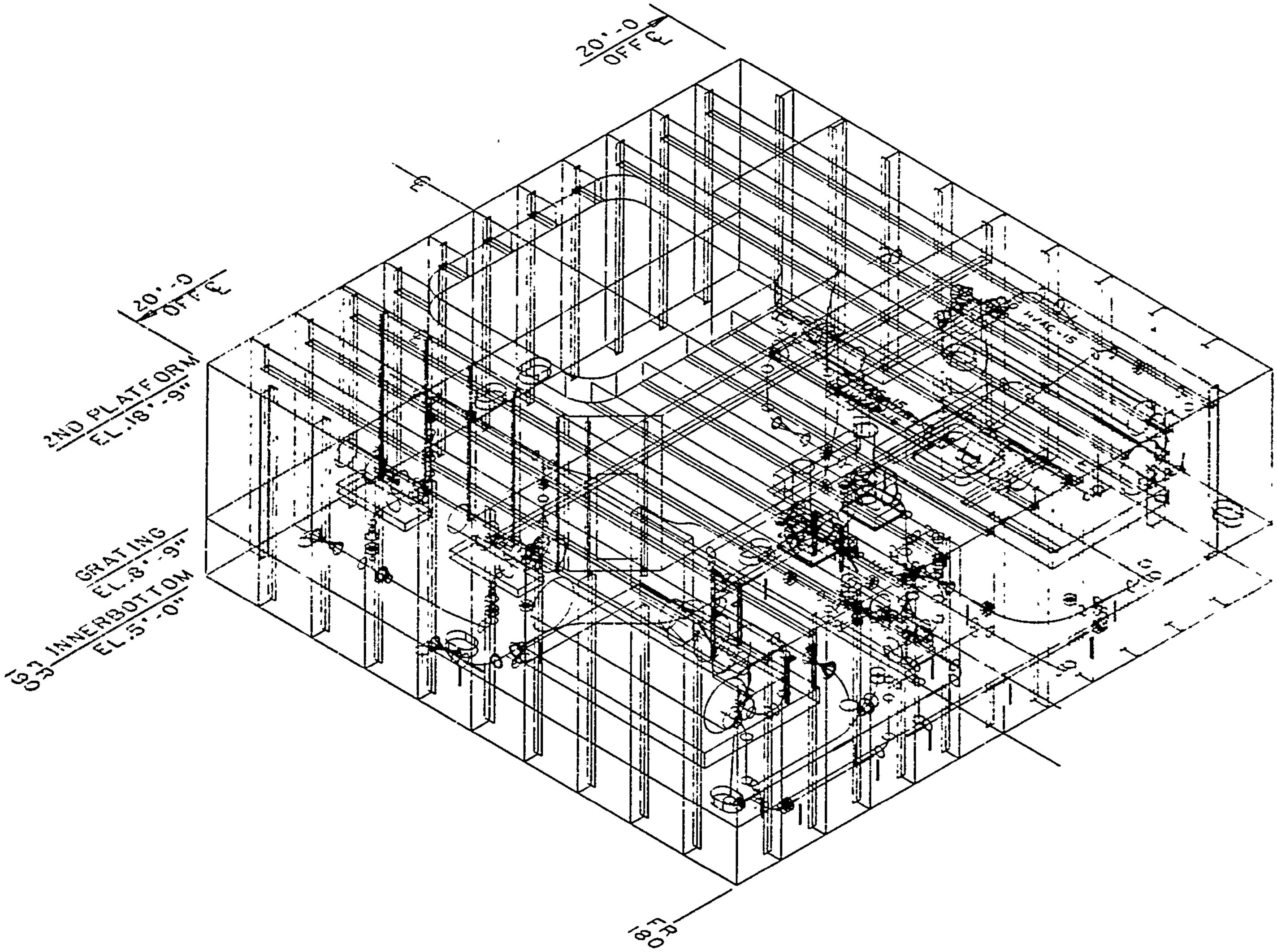


Figure 13.
System-Developed Model of USS Nimitz Compartment

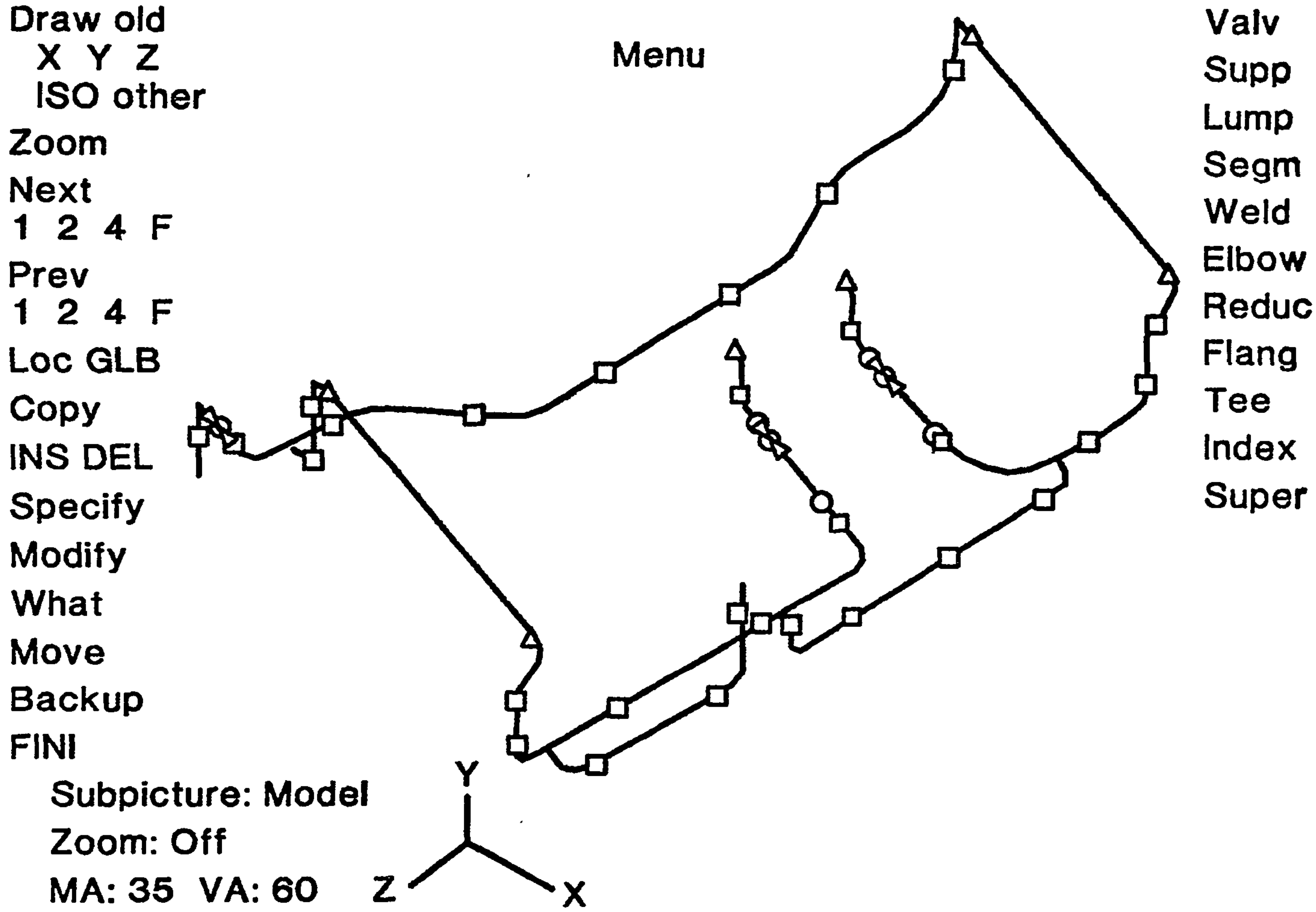


Figure 14.
System-Generated Piping Model of USS Nimitz Compartment

Table 2
Piping Analysis Results[a]

Node Point	Member Type	Stress (psi)		
		Actual	Allowable	Fraction of Allowable
185	Elbow	11947	22504	0.5309
180	Elbow	9879	22504	0.4390
1070	Elbow	9443	22504	0.4196
65	Elbow	9174	22504	0.4077
60	Elbow	8812	22504	0.3916
1105	Elbow	8163	22504	0.3628
1030	Elbow	7908	22504	0.3514
1025	Elbow	7852	22504	0.3489
326	Elbow	7229	22504	0.3212
70	Tee	7160	22504	0.3182
1115	Tee	7138	22504	0.3172
175	Reducer	7062	22504	0.3138
1240	Elbow	7000	22504	0.3111
1220	Elbow	6996	22504	0.3109
70	Tee	6972	22504	0.3098
340	Elbow	6886	22504	0.3060
1075	Elbow	6823	22504	0.3032
240	Elbow	6722	22504	0.2987
255	Tee	6664	22504	0.2961
2030	Elbow	6630	22504	0.2946

a. 20 highest Equation 11 stresses, in decreasing order of fraction of allowable

CONCLUSION

Interactive computer-based systems have been developed for the geometric modeling of areas, analysis of piping, and analysis and design of piping supports. The applicability of these systems to the design and construction of naval ships has been demonstrated. These programs provide the capability to store the design information in a computer format for long-term use, increase the quality of the engineering, minimize construction cost overruns due to errors, increase the productivity of piping and support system design, and perform design optimization studies economically. The Westinghouse computer-aided engineering systems can be used at remote sites through fully equipped Structural Analysis Mobile Units electronically linked to mainframe computers in Pittsburgh, Pennsylvania.

"SPADES" Integrated Approach to Structural Drawings & Lofting

F. Cali
President
Cali & Associates, Inc.
Metaire, LA

Mr. Cali has been President of Cali & Associates, Inc. since its inception in July , 1973. Prior positions include: Assistant Vice President of Engineering at Avondale Shipyards, Inc., New Orleans, La., and Director of Enginering at Litton Ship Systems, in Pascagoula, Mississippi. Mr. Cali has been a pioneer in the application of computer technology to shipbuilding since 1958.

He is a graduate of the Italian Naval Academy.

Floyd Charrier, Jr.
Manager, Marketing & Engineering
Cali & Associates, Inc.
Metairie, LA

Mr. Charrier has thirteen years experience in shipbuilding, ranging from Production to Engineering Supervision and Management. Prior positions include Structural Supervisor Computer Applications at Breit and Garcia, Inc. and Hull Designer/Loftsman at Avondale Shipyards, Inc.

ABSTRACT

Currently, engineering structural drawings and lofting information are produced either manually or computer aided, which results in the managing of separate data bases.

The 'SPADES' Integrated Approach allows the user to extract engineer-ing structural drawings, N/C lofting, and production control reports from one common data base.

The common data base management concept insures that once the data has been correctly loaded, all information generated will reflect the common data base information and provide continuity throughout the different phases of shipbuilding.

Some advantages of this common data base management are: greater management control, overall visibility of required information, greater revision control, overall improvement in production schedules and substantial man-hour savings.

"SPADES" INTEGRATED APPROACH TO STRUCTURAL DRAWINGS & LOFTING

The 'SPADES' Integrated Approach to structural drawings and lofting uniquely addresses the CAD/CAM demands of today by utilizing an integrated common data base approach. The methodology of an tegrated hull data base allows the 'SPADES' user to extract such information as: Engineering (structural) Design Drawings, Unit Construction Drawings, Production Control Reports and (N/C) Numerical Control Lofting tapes from the one common source - the data base.

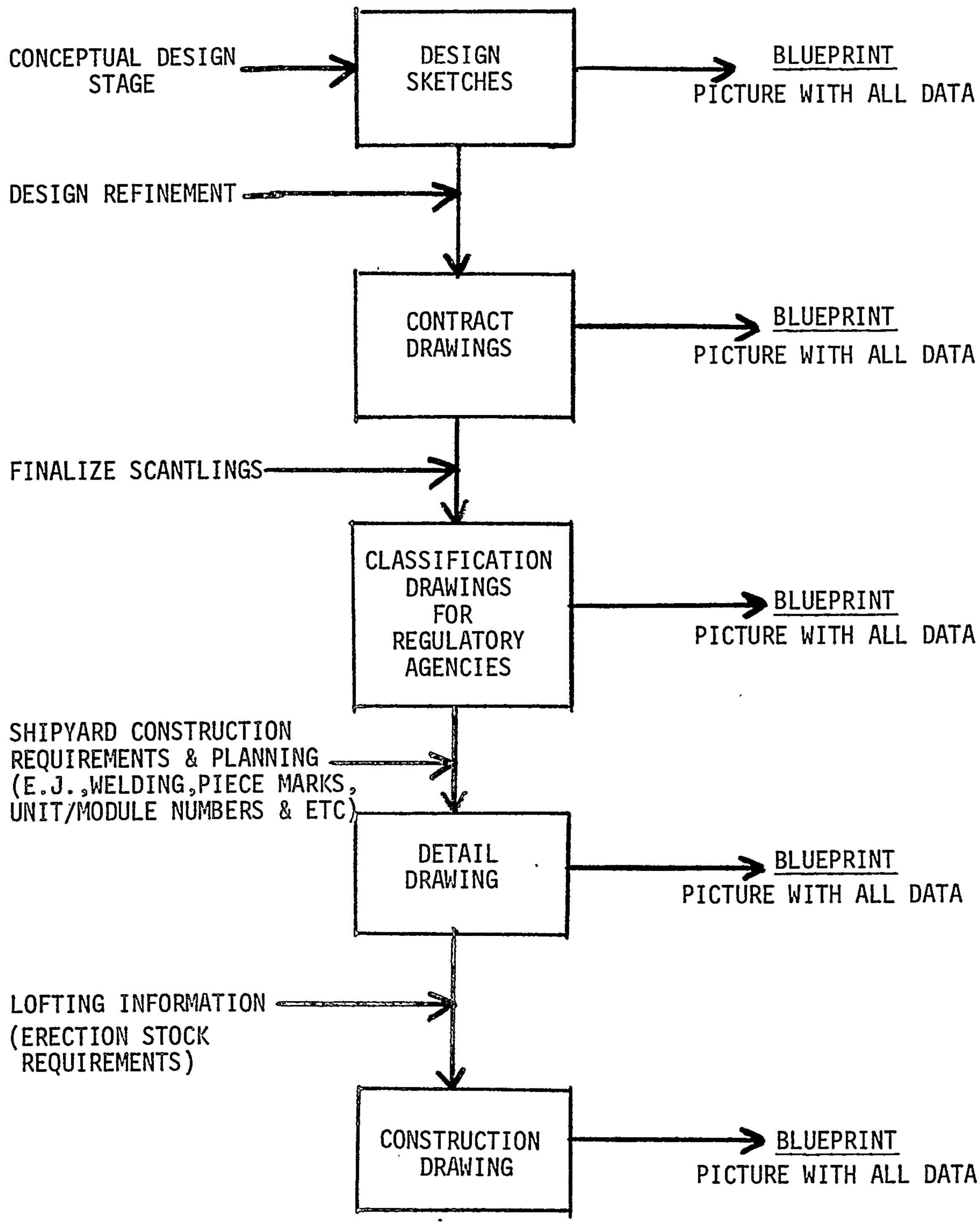
The common data base management concept insures that once the data has been correctly loaded, all output generated will reflect the comon data base information and provide continuity throughout the different phases of the shipbulding process.

The traditional method of controlling engineering and lofting information was accomplished through the original tracing of the drawing, which developed into the source document. These structural drawings would eventually be tiered in many layers with engineering, production, and lofting information intermingled.

The first tier or layer of the drawing would be the conceptual contract drawing developed for the shipyard's bid package to

MANUAL ENRICHMENT OF ORIGINAL DRAWING TRACING

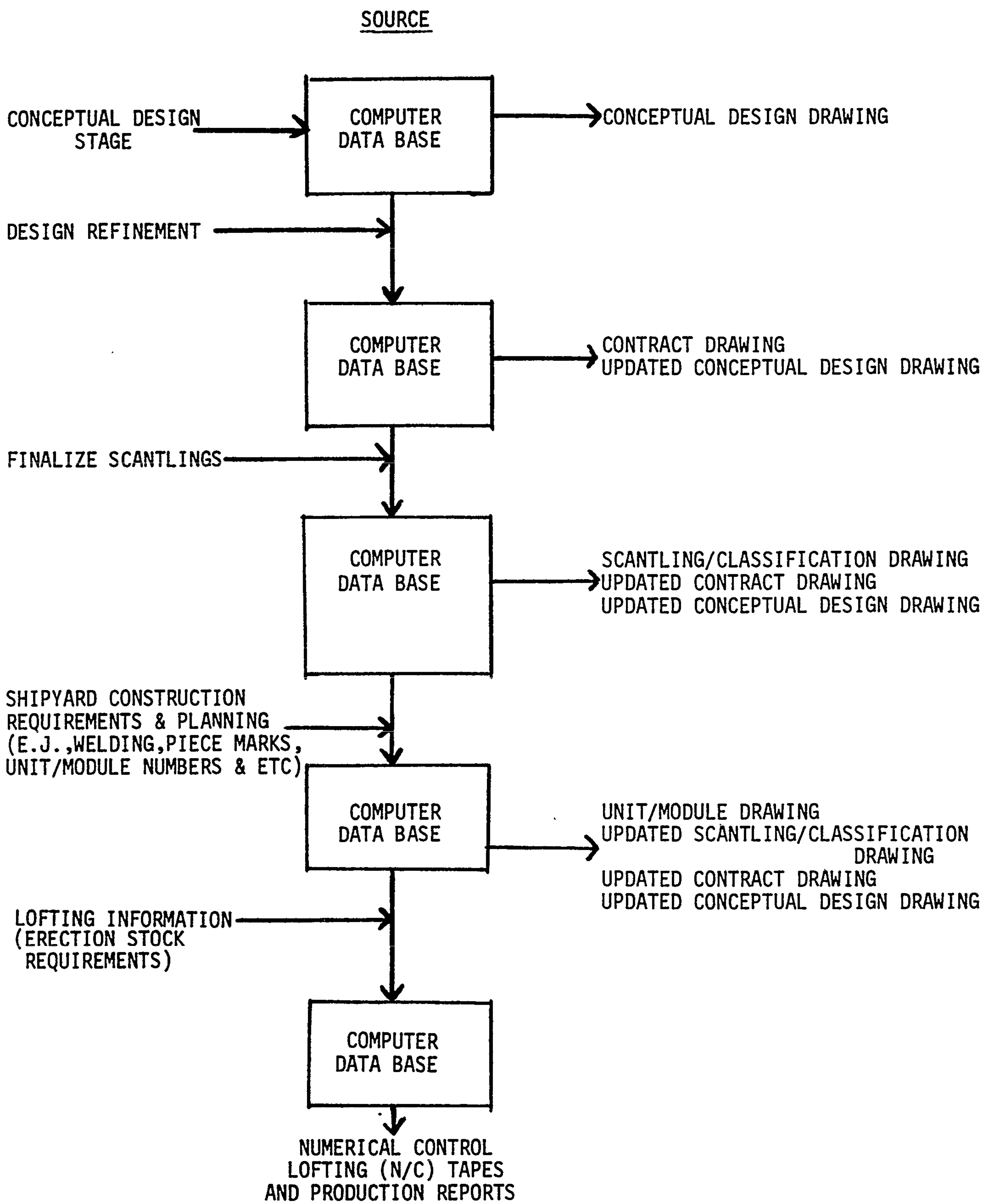
SOURCE



convey their intentions for the design and construction of the subject vessel. Once the construction contract was secured the same conceptual contract drawing package would be enriched to become the scantling/classification drawing required to obtain approval from the regulatory agencies American Bureau of Shipping (A.B.S.) and United States Coast Guard (U.S.C.G.). After receiving approval from A.B.S. and U.S.C.G., the scantling/classification drawing would undergo another alteration by becoming the shipyards consruction drawing for in-house use. This would also require the production planning information to be added such as: Erection Joints (E.J.), stock requirements and production welding information, unit numbers, piece marks and general notes as required.

Innovative shipbuilding techniques as the unit/modular concept caused a new approach in the drawing format to convey the unit/module methodology of construction. Unit/module drawings for construction would be developed from the approved scantling/classification drawings and carry similar information as the old conventional method of construction drawings, but in a booklet form with individual sheets that represent a particular sub-assembly or a number of sub-assemblies. The unit/module drawing requires additional dimensional control, labeling, multiple sheets, checking and supervision, and greater overall planning of the portions to be detailed within a given

COMPUTER ENRICHMENT OF DATA BASE



unit/module. This type of drawing became unmanageable because of revision control and the cost of managing such a system. For example, a design change during the construction phase would encompass the revising of the following areas: scantling/ classification, conventional construction or unit/module drawings, production planning information and manually lofted templates or N/C lofted tapes. This would require each source document within the system to be revised independently, with the inherent possibility of error aggravated by the interdepartmental interface problems. The ultimate result would be that the design or construction drawings and lofting might not be compatable, and regardless of what the drawings indicated the ship would be built from the lofted information.

The 'SPADES' intergrated data base approach eliminates the problem of interface by allowing the source - the data base - to be revised, which automatically changes all output information such as: Design Contract Drawings, Scantling/Classification Drawings, Unit/Module Construction Drawings, Production Control Reports, N/C Part Generation from Data Base, Automatic Nesting and N/C tapes. The 'SPADES' methodology addressed the needs of extracting different drawings for different applications. This method was impossible to manage and too costly under the old conventional method of producing drawings. With the new method of one source - the computer data base - the shipyard may select

the desired information for a particular function within their shipyard. In the new methodology the drawings are considered as blueprint copies and the data base the original tracing, with the advantage of having the capability of extracting drawings containing only the information needed by the type of drawing.

A number of 'CAD' Systems have been developed in the recent yearsl but as far as we know none of them has taken into account the need of a single data base for drawings, lofting, material controls etc.

All CAD Systems seem to have developed by trying to duplicate the traditional method of considering the tracing the source of all data and they've concentrated on reducing the cost and improving the quality of the original 'tracing'. The CAD Systems, therefore, will allow the draftsman, at his own discretion, to create a drawing which may or may not be consistent with the lofting N/C data base by which the ship will be built. The emphasis being on that right, wrong or indifferent, if the (CAD) drawing is correct and the lofting data base is wrong, the ship will be constructed wrong and if the lofting data base is correct and the independent CAD system drawings are incorrect, the ship will be built correctly0 If the choice must be made between correct drawings and correct lofting data base,

it follows that we can live with incorrect drawings but not with the reverse. It is therefore imperative that the data base must be the source of both drawings and lofting, and that our management efforts must be directed at controlling the data base.

The 'SPADES' System has approached the problem from this point of view. Changes, when necessary, are introduced as changes to the model of the ship in the data base with consequential automatic changes on both drawings and lofting data.

Generating a drawing can be compared to taking a picture of the structure in the data base using various filters to screen out data not necessary for the purpose for which the drawing is intended. The 'SPADES' drawing construction program was designed with this in mind. That is, to provide as much flexibility in the formatting and selection of the data to be presented but no capability of altering the data. If the structure as represented in the drawing is wrong, the only way to correct it is to make the appropriate changes in the data base and regenerate the drawing. Loading and maintenance of the data base is accomplished by the more experienced personnel who also plan the drawings in sketch form. Junior personnel with less experience operate the graphic terminals to generate and annotate the drawings.

It might appear, at this point, that the implication is that drawings are not important since they do not directly affect the accuracy to which the ship is built. However, until the ship is totally constructed under computer control, and we can send a mag tape to A.B.S. for approval of the design, accurate drawings must still be generated for contractual records, Regulatory Body approvals and construction guidance. Configuration management must be applied to the data base but the drawings, being the visible representation of the data base, must also be similarly controlled. The following brief description of the system shows how that is achieved in SPADES':

The key difference between the 'SPADES' approach and the conventional 'CAD' system is probably the fact that <u>no graphic file by layers, or of any sort,</u> is ever stored in the data base.

For each drawing, a set of data representing all the instructions given by the operator is stored and re-executed whenever a copy of the drawings is desired or when a drawing revision is necessary. The pictorial portion of the drawing is re-created every time from the three-dimensional model of the ship structure as it exists in the data base. All annotations added to the drawing are also re-created at that time, changing location and

contents to reflect changes that might have occurred in the data base. The location and scale of any portion of a drawing can be changed without having to relocate all associated annotations. All this is possible because a full one-to-one correspondence exists at all the times between the displayed data and entities in the data base. As for all other types of records in the 'SPADES' data base, no accidental deletion of a drawing file can occur at any time.

The system allows three different types of multi-sheets drawing formats. Two are conventional large-sheets drawings and one is to handle booklets. The title block format and drawing sizes are user defined and can be different for each ship in the data base.

Closing and opening of revisions can be done only through a separate program with password protection and from selected terminals. If a revision is closed, a drawing can be viewed and a hardcopy generated but <u>no changes of any kind</u> will be allowed. With an open revision, changes can be made anywhere, except on the write-up of the previously closed revision.

Currently, the 'SPADES' System is actively involved in the development of an interactive data base loading program, and the 3D representation of the ship structure in isometric drawings. Interactive loading of the data base allows the user to load information directly by means of a graphic terminal.

In comparison to the batch version of keypunching information into the data base, the incorporation of the interactive data base loading program will substantially reduce the number of man-hours required in loading the data base.

In the near future, the 'SPADES' System will develop the distributive systems that will be integrated with the hull data base. The hull structure and lofting, along with the piping, ventilation, electrical and outfitting, will be controlled from one common source - the data base. The data base at this level will act as a composite for checking all interferences.

The 'SPADES' methodology of the integrated data base approach provides the technological advancement required to meet the competitive demands of the worldwide shipbuilding market.

Typical 'CAD' Problems and the 'SPADES' Solution

PROBLEM	SOLUTION
A deck longitudinal, because of clearance requiremtents, has to be flipped and toe inboard instead of outboard Two scantling drawings (Deck Drawing and Transverse Bulk-heads drawings) and 20 sub-assembly construction dwgs. must be revised.	Change the data base for the relocated longitudinals. All 22 drawings are auto-matically changed except for entering the revision write-up. *Re-execute the lofting and extract automatically changed 'lofting information.
After generating all affected scantling and detail drawings. A design change requires the addition of face bars to a number of holes and/or changes of scantling and material grade.	Define to the data base the new requirements. All drawings are automatically changed to new scantlings.
An existing drawing requires re-formatting and scale changes.	Relocate and change scale of various sections of the drawing. All labels and annotations are automatically moved accordingly.
The characteristics of a welding process need to be changed.	Re-define to the data base the affected welding detail. All drawings calling for that-detail will automatically show the revised detail.

THE ENGINEERED TIME VALUES SYSTEM-A BETTER APPROACH TO PRODUCTIVITY MANAGEMENT IN MAINTENANCE

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Captain Bihr is associated with Planning Research Corporation working on the design and development of automated production management systems for maintenance and repair activities. His Navy experience includes service in all types of combat vessels from aircraft carriers to battleships,cruisers and destroyers. He commanded a destroyer tender and the Naval Amphibious base at Little Creek, Virginia.

Captain Bihr holds a BS degree in mechanical engineering from Rensselaer Polytechnic Institute and an MS degree in management science from the U.S. Naval Postgraduate School. He has undertaken extensive postgraduate studies in communications engineering and in mathematics.

ABSTRACT

The U.S. Navy has been experimenting with a maintenance management which has recorded a high rate of success in adopting industrially proven techniques for increasing productivity at the Shore Intermediate Maintenance Activities at Norfolk, Virginia and Mayport, Florida.

The Engineered Time Values System is an adaptation of commercially proven maintenance management procedures, underpinned by engineered labor performance standards for the measurement of performance, productivity and work progress. The system provides the visibility to management of what is happening in the production process so that dynamic control can be executed to maximize productive efficiency. The system is oriented to the internal management functions of workload planning/control and associated resources management. The key change from the current production management system which uses <u>inPut labor hours</u> as the measurement tool, is the shift to <u>earned hours.</u> Engineered performance standards are used to develop a standard measure of work content for each job undertaken. This work content value is adjusted to a planned man-hour figure by the addition of travel, job preparation and other allowances. The planned man-hours are then converted into earned hours incrementally as the work is accomplished. When the job is done the total of the planned hours are credited to the shop's performance. The ETV System borrows further from proven industrial engineering concepts through its use of visible, realizable performance targets, short-interval work scheduling, focus on lost production time factors , and ready-to-execute work packaging.

A truly unique feature of the ETV System is the use of interactive computer equipment to support management information needs. The Productivity Management Information Component (PMIC) of the ETV System offers dynamic, on-line ADP assistance for the functions of work induction, work planning, work status and progress, workload forecasting, materials management, technical documentation

support, labor availability and plant/equipment availability. Video terminals are positioned at distributed work stations where the functional manager can, in real time both update data and recall information needed for their production control or resource management tasks. Selected stations are provided with printers to obtain hard copy versions of the visual displays.

This paper examines the applicability of ETV System concepts to shipyard functional requirements in the areas of:

- engineered standards development
- engineered standards employment in Planning and Estimating
- materials identification, acquisition and staging
- job tracking and work progressing

THE ENGINEERED TIME VALUES SYSTEM

A BETTER APPROACH TO

PRODUCTIVITY MANAGEMENT

IN

MAINTENANCE ACTIVITIES

ETV

- A PRODUCTION MANAGEMENT SYSTEM FOR MAINTENANCE / REPAIR

FEATURING :

- THE EARNED-HOUR CONCEPT FOR WORK CONTENT MEASUREMENT
- ENGINEERED LABOR PERFORMANCE STANDARDS
- AUTOMATED
  - JOB TRACKING
  - WORK PLANNING / ESTIMATING
  - WORK LOADING
  - WORK SCHEDULING
  - WORKLOAD FORECASTING
  - PRODUCTION ANALYSIS
  - PERFORMANCE ANALYSIS
  - MATERIALS MANAGEMENT
  - PLANT RESOURCE MANAGEMENT

SCOPE OF PRESENTATION

- **BACKGROUND OF ETV**
- **EARNED HOUR CONCEPT**
- **ETV STATUS AND FEATURES**
- **ETV PRODUCTIVITY MANAGEMENT INFORMATION COMPONENT**
  - OVERVIEW
  - PLANNING
  - MATERIALS IDENTIFICATION / ACQUISITION
  - PRODUCTION CONTROL
  - QUALITY ASSURANCE
  - PERFORMANCE MONITORING
  - WORKLOAD FORECASTING
  - SCHEDULING
  - RESOURCE MANAGEMENT

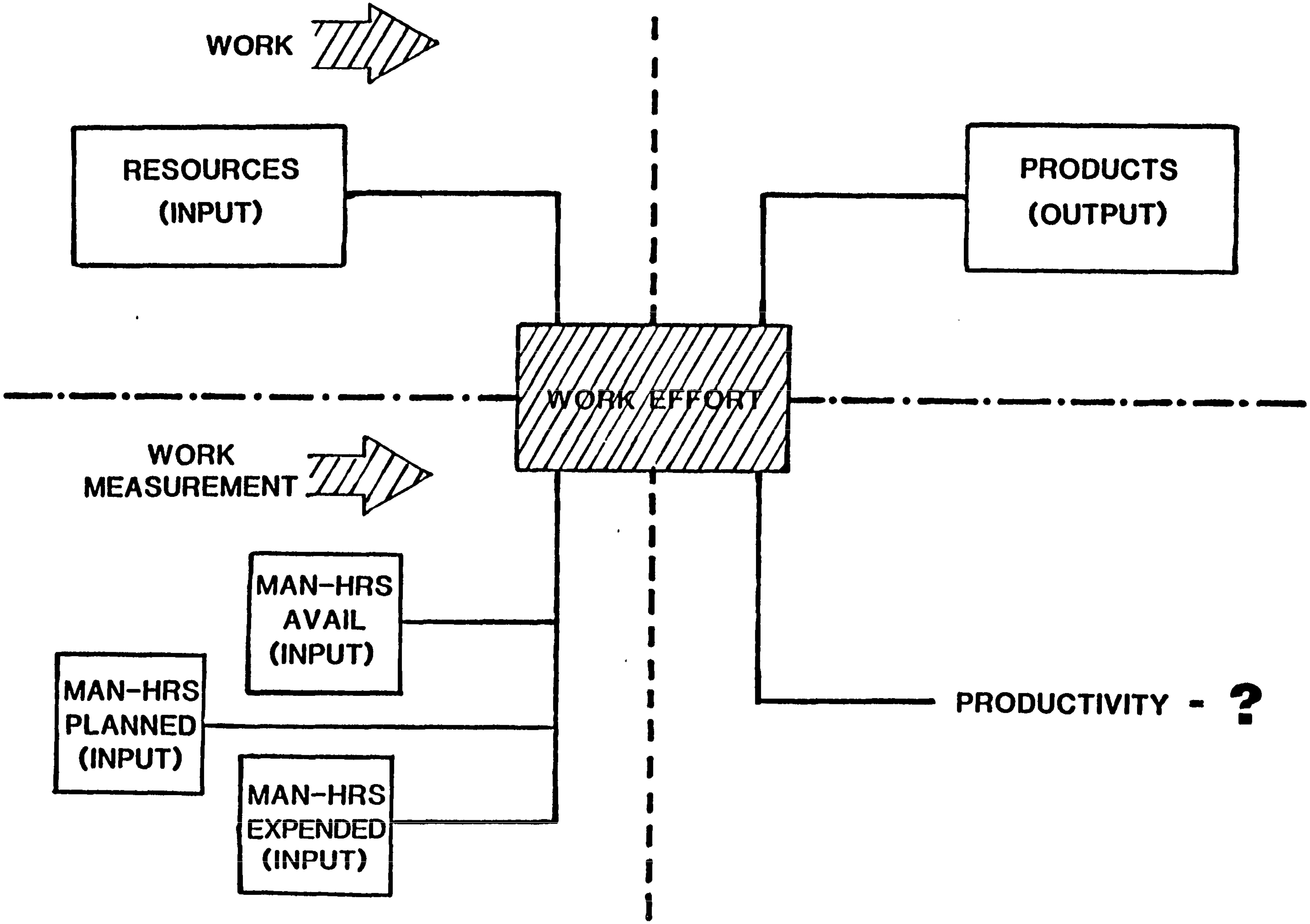
BACKGROUND

- **NAVY'S INTERMEDIATE MAINTENANCE ACTIVITIES**
  - 39 SHORE/AFLOAT ACTIVITIES
  - SOME 35 SHOPS EACH
  - HULL, MECHANICAL, ELECTRICAL, ELECTRONICS, WEAPONS
  - CAPABILITIES EXTEND INTO DEPOT AREAS OF EXPERTISE
  - SMALL – 400 TO 1200 WORKER PRODUCTIVE FORCE
- **DOD/GAO AND NAVY CONCERNED THAT PRODUCTIVITY COULD NOT BE MEASURED; HENCE,**
  - NO WAY TO GAUGE IMPACT OF PRODUCTIVITY ENHANCEMENTS
  - NO WAY TO ASSESS CAPACITIES VS FLEET WORKLOAD
  - NO WAY TO MEASURE RESOURCES
- **SO, GO TO EARNED HOURS**

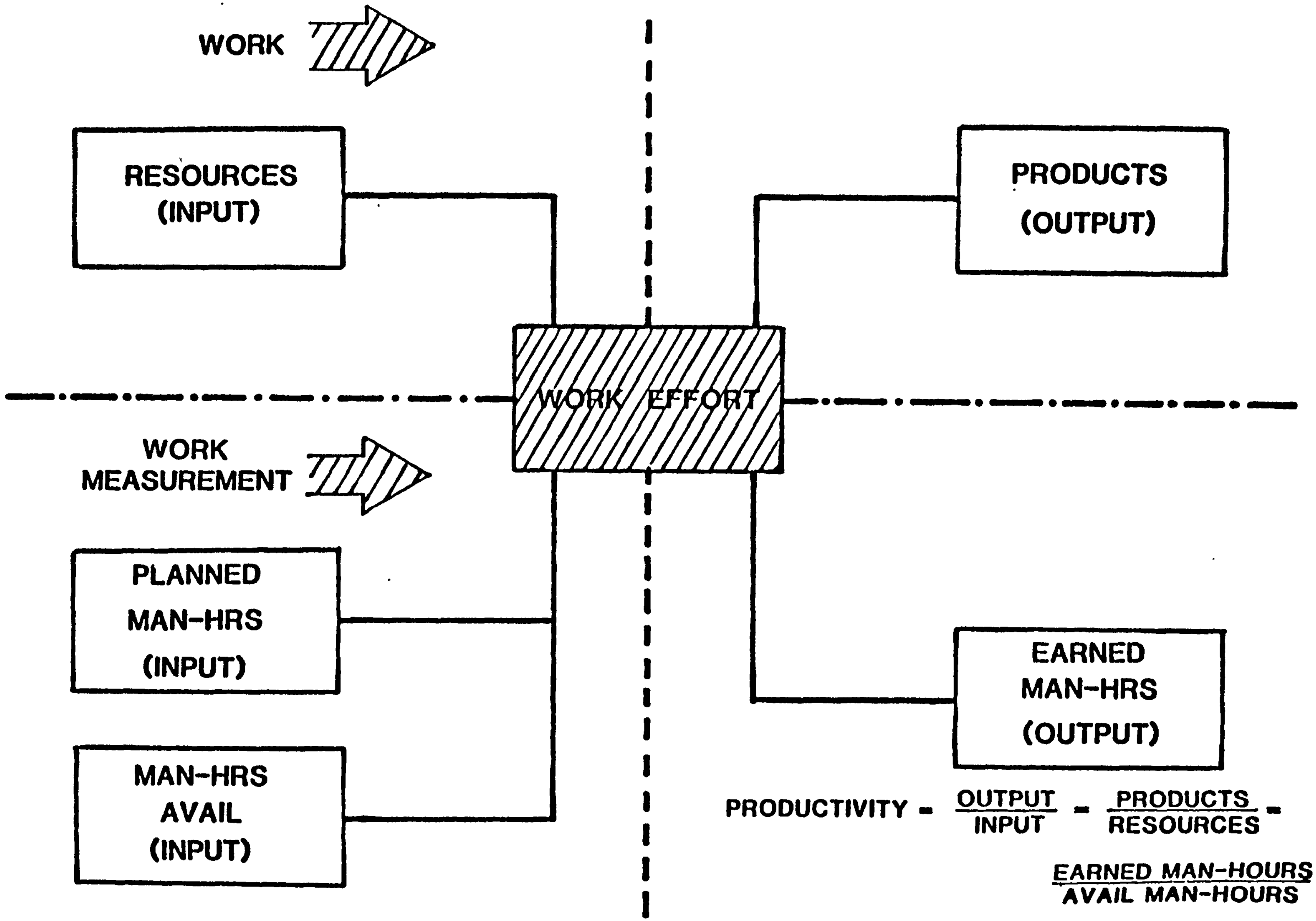
THE EARNED HOUR CONCEPT

- **FIX A WORK CONTENT VALUE TO THE JOB**
  - STANDARD HOURS + ALLOWANCES
  - PLANNED MAN-HOURS
  - SHORT INTERVAL STEPS
- **ISSUE THE JOB TO THE SHOPS TO BE EARNED**
  - INCREMENTALLY CREDIT SHOPS AS JOB ADVANCES
  - HOURS EARNED/TOTAL PLANNED HOURS = PROGRESS
- **AT SHOP LEVEL FOREMAN HAS AVAILABLE**
  - REASONABLE PERFORMANCE GOALS
  - MECHANISM TO CONTROL QUALITY
- **WORK CONTENT MEASURE ALSO USED FOR FORECASTING, CAPACITY ASSESSMENT, BUDGETING**

EXPENDED HOUR SYSTEM



EARNED HOUR SYSTEM



ETV STATUS

- EVALUATED JAN-JULY 1981 IN NORFOLK
- IMPLEMENTED SUBSEQUENTLY AT MAYPORT, NEWPORT AND SAN DIEGO
- BEING EXTENDED TO PEARL HARBOR, CHARLESTON AND LITTLE CREEK
- ACCEPTED FOR INCORPORATION INTO NAVY'S NEW MAINTENANCE MANAGEMENT SYSTEM

HOW DOES IT WORK?

- **WE DEVELOP ENGINEERED TIME VALUES (ETV) FOR THE WORK METHOD**
  - PRE-DETERMINED TIME SYSTEM BASED ON MTM
  - SUPPLEMENT WITH WORK MEASUREMENT/ HISTORICAL ESTIMATES
  - BENCH MARKS CONTAIN DETAILED METHOD/ TASK TIMES
  - PROCESS SHOPS/PRODUCT SHOPS

HOW DOES IT WORK? (CONT'D)

- **BENCH MARK DATA IS FORMATTED AND ENTERED IN COMPUTER FOR PLANNER'S USE**

- **PLANNER PLANS JOB ON VIDEO TERMINAL**
  - INTERACTIVE CONVERSATIONAL DIALOGUE
  - GUIDES HIM THROUGH PLANNING PROCESS
  - INCLUDES APPLICATION OF ALLOWANCES

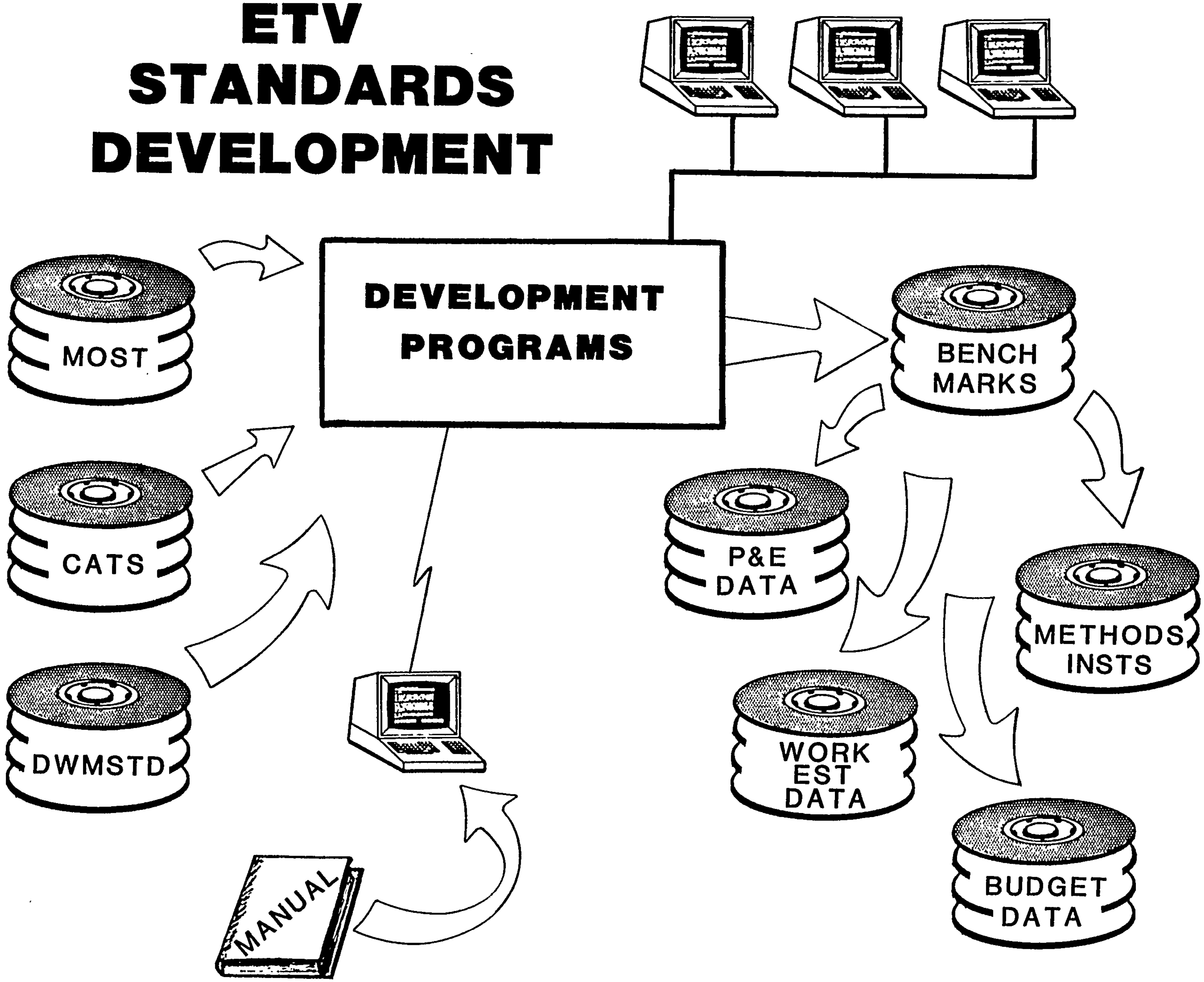
- **COMPUTER PRINTS WORKSHEET**
  - SELECTED WORK STEPS
  - PLANNED MAN-HOURS
  - REFERENCES/SPECIAL INSTRUCTIONS
  - QC/QA CHECKPOINTS

ETV STANDARDS DEVELOPMENT

- **CURRENTLY MANUAL**
- **CONVERTING TO A FULLY AUTOMATED SYSTEM**
  - USE COMPUTER AIDED SECONDARY MTM STANDARDS SYSTEM SUCH AS MOST*
  - ACCESS DOD - SPONSORED CATS DATA BASE AND OTHERS
  - STORE DEVELOPED BENCHMARKS ON DISK FOR FAST REVIEW AND UPDATE DOWN TO WORK ELEMENT LEVEL
  - BENCHMARK FILE ELECTRONICALLY FORMATTED FOR PLANNER USE
  - ADDITIONALLY FORMATTED FOR USE OF WORK BROKERS AND BUDGET ANALYSTS

* H.B.MAYNARD COMPANY

ETV STANDARDS DEVELOPMENT



ETV THRUSTS

- **REMOVE SUPERVISOR'S NON-PRODUCTIVE TASKING**
- **PROMOTE STRONG FRONT END PLANNING**
- **IDENTIFY MATERIALS TO THE JOB ORDER**
- **ISSUE EXECUTABLE WORK**
- **DYNAMICALLY TRACK WORK STATUS**
- **PROMOTE SHORT INTERVAL SCHEDULING**
- **FOCUS MANAGEMENT ATTENTION ON REDUCING THE DELTAS**
  - UTILIZATION DEGRADATION
  - PERFORMANCE DEGRADATION
  - LOST PRODUCTION CAUSES
  - LACK OF WORK

THE ETV SYSTEM

PRODUCTIVITY

MANAGEMENT

INFORMATION

COMPONENT

INTERACTIVE, MULTI-TASK, REAL TIME INFORMATION SYSTEM

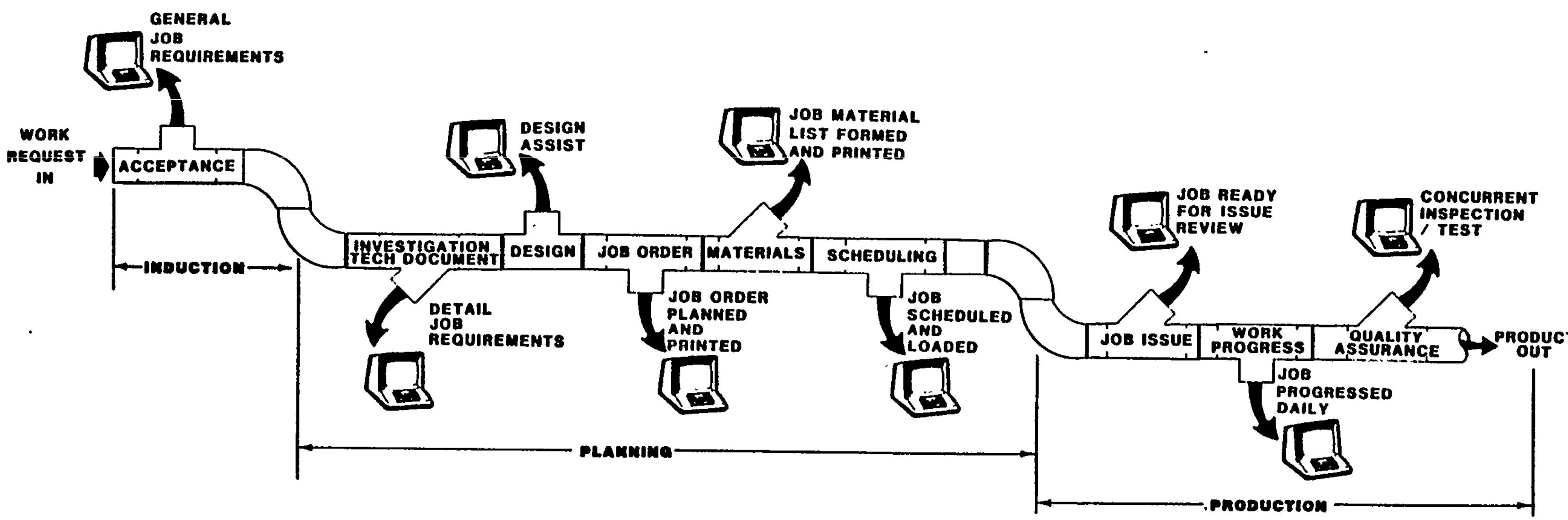
THE PMIC PROVIDES

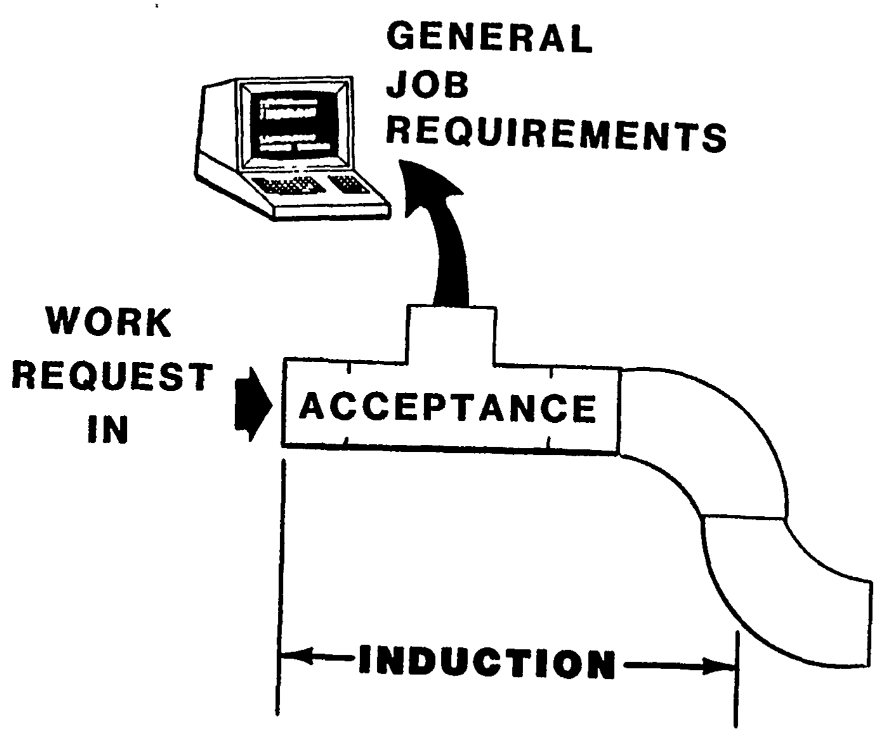
- **CURRENT JOB STATUS FROM INDUCTION OF WORK REQUEST THROUGH**
    - PLANNING
    - DESIGN
    - SCHEDULING
    - ISSUING
    - WORK PROGRESSING TO COMPLETION
    - QA
    - TEST

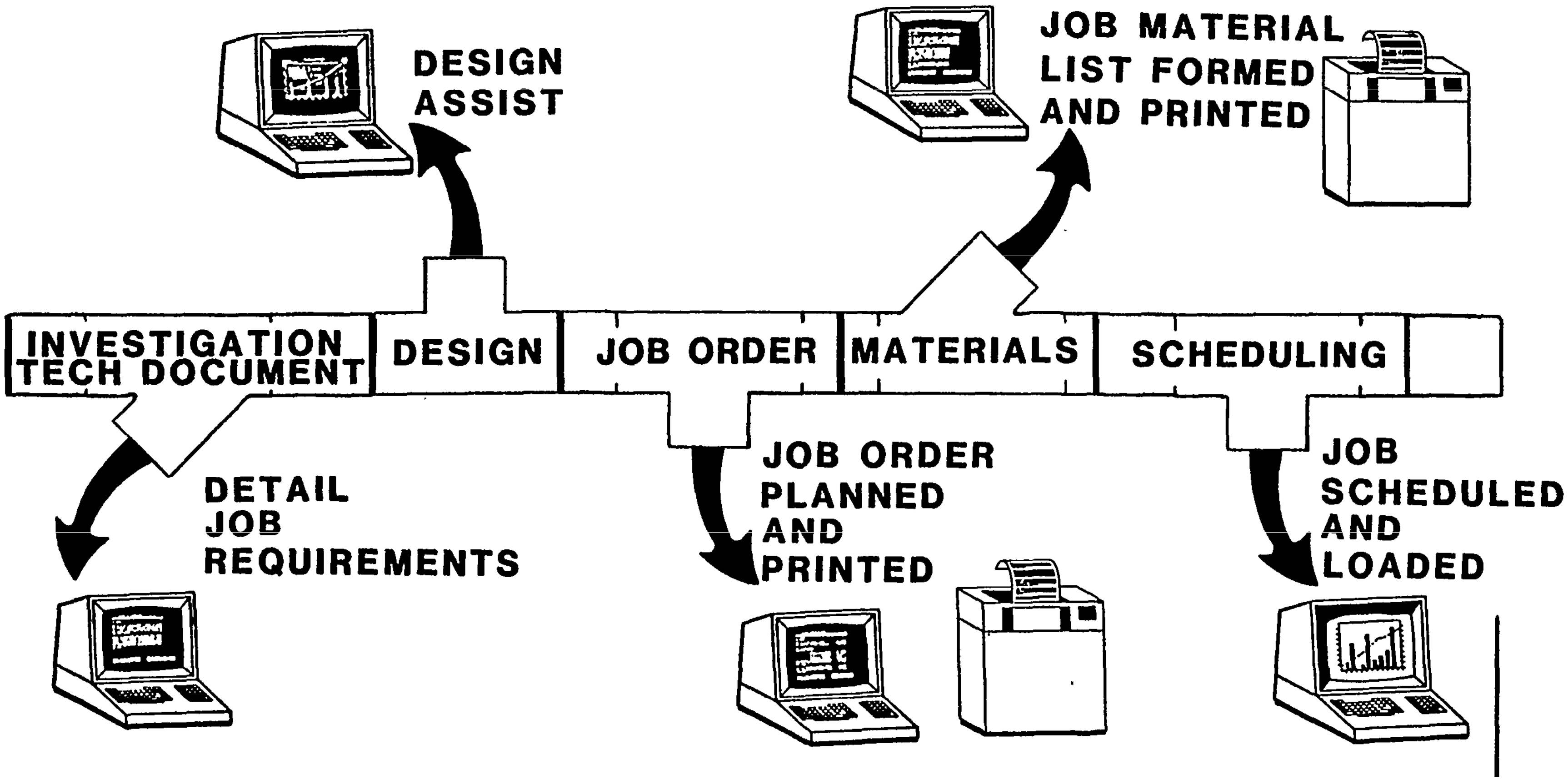
AND :

- PLANNING ASSIST
  (INCLUDING MATERIALS ID/ORDERING)
- SCHEDULING ASSIST
- WORKLOAD FORECAST
- PRODUCTION CONTROL
- DISPLAYS/REPORTS
- RESOURCE MANAGEMENT

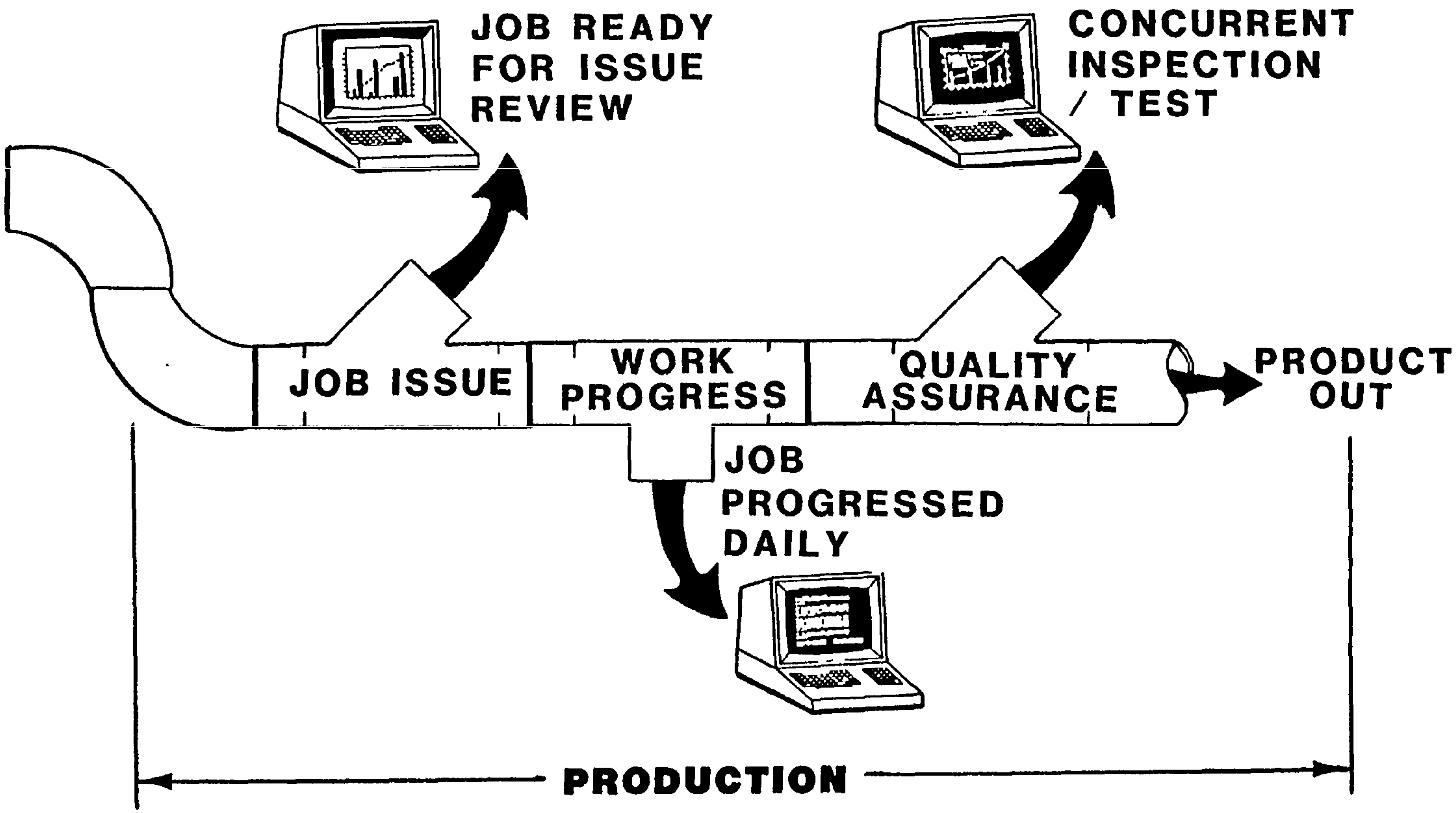
THE FLOW OF PRODUCTION CONTROL




GENERAL
JOB
REQUIREMENTS
WORK
REQUEST
IN
ACCEPTANCE
INDUCTION


DESIGN
ASSIST
JOB MATERIAL
LIST FORMED
AND PRINTED
INVESTIGATION
TECH DOCUMENT
DESIGN
JOB ORDER
MATERIALS
SCHEDULING
DETAIL
JOB
REQUIREMENTS
JOB ORDER
PLANNED
AND
PRINTED
JOB
SCHEDULED
AND
LOADED

PLANNING


JOB READY
FOR ISSUE
REVIEW
CONCURRENT
INSPECTION
/ TEST
JOB ISSUE
WORK
PROGRESS
QUALITY
ASSURANCE
PRODUCT
OUT
JOB
PROGRESSED
DAILY
PRODUCTION

PLANNING UNDER ETV FOR CUSTOM/UNIQUE JOBS

- **STANDARD DATA ORGANIZED AND SELECTED HIERARCHIALLY**

  KEY EVENT
    JOB
      KEY OPERATION
        TASK
          COMPONENT OF WORK
            WORK OPERATION

- **PLANNER SELECTS WORK ELEMENTS AT LEVEL DESIRED BY MENU SELECTION - COMPUTER ACCUMULATES TASK TIMES**

MORE ON CUSTOM/UNIQUE JOBS

- **COMPUTER PROMPTS PLANNER THROUGH HIS NORMAL MENTAL PLANNING PROCESS**
- **COMPUTER ADDS ALLOWANCES TO GENERATE PLANNED TIME**
    - JOB PREPARATION
    - SHOP/SHIP/SHOP TRAVEL
    - SHIPBOARD WORK ENVIRONMENT COMPLEXITY FACTOR
    - PERSONAL/REST/DELAY
- **JOB ORDER PRODUCED ON PRINTER**

PLANNING UNDER ETV (CONT'D)

FOR REPETITIVE JOBS

- PLANNER SELECTS PRE-PLANNED JOB ORDER
- PLANNER ADDS/DELETES WORK ELEMENTS IF NECESSARY
- COMPUTER ADDS ALLOWANCES AS IN CUSTOM JOB
- JOB ORDER PRODUCED ON PRINTER

ETV AUTOMATED PLANNING
REPRESENTATIVE DATA BASE INSTALLED

- **FLEXIBLE HOSE**
  - MANUFACTURE, TEST, AND INSPECT LP,MP, HP HOSES
  - ALL PRESSURE / SERVICES
- **METAL WORKING**
  - 11 MACHINE CATEGORIES, 30 MATERIAL TYPES
  - (PROCESS WORK)
  - PRE-PLANNED ITEMS ASSISTING 8 WORK CENTERS
  - (PRODUCT WORK)
- **PIPEFITTING**
  - BUTT AND SOCKET WELDING
  - BRAZING/SOLDERING
  - ALL ASSOCIATED OPERATIONS
  - ALL PRESSURE/TEMP/SERVICES

ETV AUTOMATED PLANNING
REPRESENTATIVE DATA BASE INSTALLED

- **MOTOR RECONDITIONING / REWIND**
  - ALL SIZES/CONFIGURATIONS A/C MOTORS
  - DISASSEMBLY/COIL WINDING/ASSEMBLY
  - MACHINING/TEST/BALANCING & SOUND ANALYSIS

- **VALVE REPAIR**
  - LOW PRESSURE-ALL SERVICES
  - HIGH PRESSURE-ALL SERVICES
  - REGULATORS
  - REDUCERS
  - RELIEF

- **PUMP REPAIR**
  - CLOSE-COUPLED CENTRIFUGAL
  - SINGLE STAGE CENTRIFUGAL
  - MULTI-STAGE CENTRIFUGAL
  - VANE

- **OUTSIDE ELECTRICAL**
  - REPAIR / OVERHAUL VARIOUS (36 ITEMS) ELECTRICAL EQUIPMENT
  - SHIP AND SHOP WORK

ETV AUTOMATED PLANNING
REPRESENTATIVE DATA BASE INSTALLED

- **LAGGING / INSULATION**

  ALL PROCESSES (REMOVAL, REPLACEMENT - ASBESTOS RIPOUTS)

- **SHEETMETAL / STRUCTURAL METAL WORKING**

  ALL PROCESSES (CUTTING, GRINDING, BURNING, WELDING, SOLDERING ETC.)

- **WELDING**

  H.P. AND L.P. PIPE AND PLATE (SHOP & FIELD) AUTO. WELD POSITIONERS

- **NONDESTRUCTIVE TESTING**

  VT, PT, MT, UT, RT, ACID SPOT TESTING

ETV AUTOMATED PLANNING
REPRESENTATIVE DATA BASE INSTALLED

- **MACHINERY REPAIR**

  AUX. STEAM TURBINES
  SPRAY NOZZLES
  RECIPROCATING PUMPS
  REMOTE OPERATING CABLES
  HEAT EXCHANGERS
  FORCED DRAFT BLOWERS

  TURBINE BRAKE ASSEMBLY
  PROPELLER BRAKE ASSEMBLY
  PUMP & MOTOR UNIT REPLACEMENTS
  LINE & SHAFT BEARING
  OVERHAUL DIST. PLANT EDUCTORS

  FFG7 CLASS

- **DIESELS**

  WESTERBEKE AND G.M. (VARIOUS MODEL NOS.)

- **BOILER REPAIR**

  600LB & 1200LB PLANT REPAIR PROCESSES
  TUBE AND REFRACTORY REPAIR/REPLACEMENT

ETV AUTOMATED PLANNING
REPRESENTATIVE DATA BASE INSTALLED

- INJECTOR OVERHAUL
- MOVIE PROJECTOR REPAIR
- GYROCOMPASS OVERHAUL / REPAIR
- IC COMMUNICATIONS EQUIPMENT REPAIR
- ELECTRONICS REPAIR/CALIBRATION
- TELETYPE REPAIR

```
38A - LWC             S H I P  /  S H O P    W O R K S H E E T      ***VERIFICATION***
  USS JOHN KING                         SIMA NORFOLK                     08/10/83 @ 0833
    UIC: 04669  W/C: EM01  JSN: A003          PAGE:  1          PLNR: LAWRENCE
      SHIPBOARD COMPLEXITY FACTOR: A                      SHIP TRAVEL TIME ZONE: 1
JOB DESC: CHANGE-OUT DISTILLATE PUMP                              JPF-SHIP = C    SHOP = A
                                                                   RT-SHIP = 1    SHOP = O
APL/AEL:
-------------------------------------------------------------------------------------------
                                                               ------P L A N N E D-----
REF        W O R K    T O    B E    P E R F O R M E D          ---S H I P-- --S H O P--
 NO                                                             M   QTY  C  M   QTY  C
                                                                   E.T.V.       E.T.V.

    PUMPS & MOTORS
     DISTILLATE
      FFG-7 CLASS
===========================================================================================
001     PUMP & MOTOR REPLACEMENT                               *            *///////////
          QUARTERDECK TO JOB SITE                              *       1 __*///////////
---------------------------------------------------------------*_____.1670__*LLLLLLLLLLL
002       VERIFY SYSTEM TAG-OUT----DISCONNECT & REMOVE PUMP *            *///////////
          & MOTOR UNIT & INSPECT FOUNDATION                    *       1 __*///////////
---------------------------------------------------------------*___1.1194__*LLLLLLLLLLL
003       JOB SITE TO QUARTERDECK                              *       1 __*///////////
---------------------------------------------------------------*_____.1670__*LLLLLLLLLLL
004       INSP/PREP REPLACEMENT PMP & MOTOR UNIT FOR           *///////////*
          INSTALLATION                                         *///////////*       1 __
---------------------------------------------------------------*LLLLLLLLLLL*_____.4257__
005       QUARTERDECK TO JOB SITE                              *       1 __*///////////
---------------------------------------------------------------*_____.1670__*LLLLLLLLLLL
006       INSTALL, CONNECT & ALIGN PUMP & MOTOR UNIT           *       1 __*///////////
---------------------------------------------------------------*___1.2092__*LLLLLLLLLLL
007       PERFORM OPERATIONAL TEST & INSPECTION OF PUMP &      *            *///////////
          MOTOR UNIT                                           *       1 __*///////////
---------------------------------------------------------------*___4.5170__*LLLLLLLLLLL
008       JOB SITE TO QUARTERDECK                              *       1 __*///////////
---------------------------------------------------------------*_____.1670__*LLLLLLLLLLL
*******************************************************************************************
        S T A R T    S T O P **      P L A N N E D - MHOURS:   12.7          .7
                              **
  DATE: ________   ________  **          T O T A L - MHOURS:        13.3
                              **
  TIME: ________   ________  ** U N A T T E N D E D -  HOURS:     .0           .0
                              **
                              **   S C H E D U L E D -  DAYS:     2            1
*******************************************************************************************
U N P L A N N E D    C O M P O N E N T S    O F    W O R K:




===========================================================================================
NOTE: 1.  COLUMN 'M' INDICATES NUMBER OF MEN IF MORE THAN 1 MAN FOR SHOP WORK OR
            2 MEN FOR SHIP WORK.
      2.  USE COLUMN 'C' TO CHECK-OFF WORK COMPLETED.
      3.  UNPLANNED COMPONENTS OF WORK - LIST MASTER WORKSHEET INDEX NUMBER OF THOSE
            COMPONENTS OF WORK COMPLETED BUT UNPLANNED.  ALSO SHOW QUANTITY IF APPL.
```

AUTOMATED MATERIALS IDENTIFICATION / ACQUISITION

IDENTIFICATION

- ENTER REQUIREMENTS AT PLANNING TIME
- IF REPETITIVE WORK, PRE-PLANNED JML ACCESSED
- INVENTORIES AUTOMATICALLY TAPPED FOR AVAILABILITY

LOCATION / STAGING

- IF ITEMS AVAILABLE IN SHOP STORES, SO INDICATED
- IF ITEMS AVAILABLE IN CENTRAL INVENTORY,
    - INVENTORY ACCOUNT DEBITED
    - PRE-STAGE SUSPENSE ACCOUNT CREDITED
    - PICKING TICKET PRODUCED FOR STAGING
    - JOB MATERIAL LIST PRODUCED

AUTOMATED MATERIALS IDENTIFICATION / ACQUISITION

ORDERING

- **IF ITEM NOT AVAILABLE**
  - SUPPLY ORDER POINT RECEIVES JML
  - REQUISITION / PURCHASING INFORMATION ADDED
  - PURCHASE ORDERS PRODUCED
  - INVENTORY ACCOUNT ADJUSTED

STATUS

- **EDD OF LATEST DUE-IN ITEM**
- **CONTINUALLY FLAGGED IN STATUS REPORTS**

AUTOMATED MATERIALS IDENTIFICATION / ACQUISITION

RECEIVING

- **DATA ON RECEIPTS ENTERED IN SYSTEM AT RECEIVING DESK**
  - INVENTORY ACCOUNT ADJUSTED
  - MATERIAL REQUIREMENTS FILE UPDATED
- **"PUT" TICKET PRODUCED FOR JOB-RELATED ITEMS**

FINANCIAL

- **MATERIALS COSTS COLLECTED BY :**
  - CATEGORY
  - JOB
  - CUSTOMER SHIP

PRODUCTION CONTROL EMPHASIS

- UPDATE JOB PROGRESS DAILY
- INJECT SPECIAL STATUS CODES ANYTIME
- STRESS VIDEO SCREENS IN LIEU OF PAPER
- MANAGE BY EXCEPTION
- USE GRAPHICS
- MAINTAIN JOB HISTORY - WOMB TO TOMB
- DISPLAY STATUS BY SHOP, GROUP,
  CUSTOMER SHIP, KEY EVENT,
  WORK CATEGORY, ETC.
- TRACK LOST PRODUCTION CAUSES / TIME

ETV-PMIC/062 STATISTICAL SUMMARY - BY REPAIR DIVISION/GROUP SIMA NORFOLK

	UNASG	R1	R2	R3	R4	R5	OTHER	TOTAL
INDUCTED -----	0	11	15	4	3	1	4	38
PLANNING -----		96	334	41	25	52	5	553
OVRDUE ----		0	0	0	0	0	0	0
SCHEDULING ---		94	225	40	4	26	3	392
PLN HRS ---		2947	6585	1368	256	1064	92	12312
PREP TO ISS --		21	61	5	7	21	1	116
PLN HRS -		779	1839	132	250	113	16	3129
JOBS-IN-PROG -		131	269	55	31	110	0	596
REM HRS -		3973	6520	1457	843	2231	0	15024
TOTAL JOBS ---	0	353	904	145	70	210	13	1695

09/08/82 17:26:18

SIMULATED CRT MONITOR SCREEN

E N G I N E E R E D   T I M E   V A L U E S
JOB STATUS UIC SUMMARY BY SHIP
DATE: 08/10/83 & TIME: 0800

SIMA NORFOLK
RPT NO: ETV681JTA
PAGE 3

UIC: 20068 USS AINSWORTH   HULL: FF 1090   AVAILABILITY: 01AUG83 - 31AUG83

W/C	JSN	CSMP SUMMARY	T/A	LWC	R/HR	O/O	LATEST ACTION DATE	CODE	REASON	REMARKS
WD01	1344	MFG COVERS	SIMAV	74A	7	100	08JUL	30	SHOP-COMP-UNSIGND	
WD01	1345	MFG COVERS	SIMAV	74A	19		28JUN			I/S 11JUL3-15JUL3
WD01	1346	MFG/INSTL GRIPE COVERS	IMAV	74A			07JUN	6A	SF/STD STK ITM	RO CONCUR - TR
WD01	1349	MFG DKN SHIP CURTAIN FRAMES	SIMAV	11A			01JUL	72	PE-SHIPS-OPS	SPLNR BROCK HT
WG01	0604	REPL PLUG WTR ALARM SWITCH	SIMAV	51G		100	30JUN	1	COMP-PARTS FR SUP	COMPLETED
WG01	0651	TEST 45 CAL PISTOL	IMAV	93A	3		01JUL			I/S 18JUL3-22JUL3
WG02	0401	REMOVE AN SHIP DIRECTOR	SIMAV	72A			07JUL	72	PE-SHIPS-OPS	SPLNR MCDONALD
WG02	0402	REMOVE AN SHIP COMPUTER	SIMAV	72A			07JUL	72	PE-SHIPS-OPS	SPLNR MANN
WG02	0403	MFG MK 68 DIRECTOR COVER	SIMAV	64A			01JUL			SPLNR BROCK HT
WS01	0780	MFG DECK DRN BAFFLING	IMAV	11A	4		06JUL			SCH 01AUG3-05AUG3
WS01	0804	MFG CONTROL BOX COVER	SIMAV	11A	9		22JUN			SCH 01AUG3-05AUG3
WS01	0811	WT TEST RAIL HOIST	IMAV	72D	28		01JUL			I/S 18JUL3-22JUL3
WS01	0838	WT TEST STRONGBACK	SIMAV	72D			17JUN	6I	TESTWITH WS010811	RO CONCUR - PE
WS01	0871	WT TEST TORPEDO DOLLY'S	SIMAV	72D			27JUN	6D	LACK OF FACIL	RO CONCUR - PE
WS01	0883	REPL WIRING ASROC CARRIAGE	SIMAV	38B			07JUL	72	PE-SHIPS-OPS	SPLNR MCDONALD
WS01	0885	REPL CLAM SHELL COVERS	SIMAV	38B			07JUL	72	PE-SHIPS-OPS	SPLNR MCDONALD
WS02	1660	REMOVE AN SHIPOFF HOIST	SIMAV	72A			07JUL	72	PE-SHIPS-OPS	SPLNR MANN

..... NO MORE RECORDS .....

ETV - PMIC SUPPORT FOR QA

ETV SYSTEM PROVIDES

BASIS FOR

- DISCRETE WORK STEPS ON AUTOMATED / MANUAL WORKSHEETS
- TRACKING OF ENTIRE PROCESS
- GENERATION OF JML

CONCEPT

- COMPUTER-ASSISTED SELECTION OF QA FORMS / REFERENCES
- INTEGRATE QA REVIEW STEPS / REFERENCES INTO WORKSHEET
- TRACK IN REAL TIME CONTROLLED WORK PACKAGE REVIEW/APPROVAL PROCESS

ETV - PMIC SUPPORT FOR QA

BENEFITS

- REDUCED PAPERWORK
  - SHORTENED PLANNING TIME
  - REAL TIME CWP STATUS AVAILABLE
- ELECTRONIC AUDIT TRAIL
  - BETTER DISCIPLINED CWP DEVELOPMENT / EXECUTION
  - QUICK RETRIEVAL OF PRE-PLANNED CWP PACKAGES

IMPROVEMENTS IN PRODUCTION CONTROL

PROVIDED BY :

- **ABILITY TO PROGRESS EACH JOB ACCURATELY**
  - EARNED MAN-HOURS / % COMPLETE
- **ABILITY TO MONITOR AND CONTROL WORKLOAD**
  - BY SHOP
  - REMAINING LOAD VS UNUSED CAPACITY
  - OPTIMIZE RESOURCES
- **ABILITY TO MONITOR PLANT CAPABILITY STATUS**
  - END RUN CHOKE POINTS
- **QUALITY ASSURANCE AUDIT TRAIL**

PERFORMANCE REPORTING

- **WEEKLY ANALYSIS OF PERFORMANCE, UTILIZATION AND PRODUCTIVITY**
- **SUMMARY REPORTS**

PART I – OVERALL SUMMARY

- FOR ALL SHOPS
- 5 DATA ELEMENTS
- PLUS 6–WK RUNNING AVG FOR EACH

PART II – UTILIZATION SUMMARY

- DETAILS UTILIZATION LOSSES – CAUSES/TIME LOST
- ACROSS ALL SHOPS

PART III – LOST PRODUCTIVE TIME

- ACROSS ALL SHOPS
- TEN HIGHEST CATEGORIES / TIME LOST

PERFORMANCE REPORTING (CONT'D)

DETAILED REPORTS - BY SHOP

- **PART I - MAN-HOURS DISTRIBUTION**
  - 10 DATA ELEMENTS
  - 6-WK RUNNING AVG FOR SELECTED ELEMENTS
- **PART II - MAN-HOUR INDICES**
  - 8 DATA ELEMENTS
  - PLUS 6-WK RUNNING AVG FOR EACH
- **PART III - UTILIZATION LOSSES**
  - 9 CATEGORIES / TIME LOST
- **PART IV - LOST PRODUCTIVE TIME**
  - 26 CATEGORIES / TIME LOST

PERFORMANCE REPORTING (CONT'D)

- MONTHLY REPORTS
  - FOR EXTERNAL REPORTING AND INTERNAL USE
- PART B - PERFORMANCE
  - BY GROUP / SHOP
  - 6 DATA ELEMENTS
  - PLUS 3-MONTH RUNNING AVG FOR EACH
- PART II - UTILIZATION
  - ACROSS ALL SHOPS
  - 9 DATA ELEMENTS
  - PLUS 3-MONTH RUNNING AVG FOR EACH

WORKLOAD FORECAST METHODOLOGY

ALL DYNAMIC VIDEO DISPLAYS

- **SHORT RANGE**
  - CURRENT WEEK PLUS 2 WEEKS AHEAD
  - DISPLAYS FORECAST CAPACITY, SCHEDULED LOAD AND UNUSED CAPACITY BY SHOP
- **WORK CATEGORY SUMMARY**
  - FOR ANY WEEK IN 30-WEEK WINDOW
  - DISPLAYS SCHEDULED LOAD AND PRO-RATA ALLOCATION OF UNUSED CAPACITY BY WORK CATEGORY FOR EACH SHOP
- **WORKLOAD FORECAST - DETAIL**
  - FOR ANY WEEK IN 30-WEEK WINDOW
  - DISPLAYS ALL JOBS BY CUSTOMER SHIP FOR SELECTED SHOP
  - DATA ELEMENTS INCLUDE PRIORITY, DEADLINE DATES, SCHEDULED START/STOP DATES

WORKLOAD FORECAST METHODOLOGY
(CONT'D)

- **WORKLOAD FORECAST EXTENDED SUMMARY**
  - BY SHOP
  - 30-WEEK NUMERIC REPORT
  - 17-WEEK GRAPHIC REPORT
  - DISPLAYS SCHEDULED LOAD AND UNUSED CAPACITY

PAPER REPORTS

- **ALL VIDEO DISPLAYS MAY BE PRINTED**

RESOURCE MANAGEMENT CATEGORIES

- **STATIC - CAPABILITIES INFORMATION**
  - PLANT / EQUIPMENT
  - PARTS MANUFACTURING
  - MATERIALS HANDLING EQUIPMENT
  - INDUSTRIAL PROCESSES
  - TOOLS
  - TEST EQUIPMENT
  - CRITICAL WORK FORCE SKILLS
  - LIBRARY / REPRODUCTION
  - DESIGN / LABORATORY

- **DYNAMIC - CAPACITY / AVAILABILITY INFORMATION**
  - FACILITIES
  - EQUIPMENT / TEST GEAR
  - LABOR CAPACITY / KEY SKILLS
  - MATERIALS INVENTORY
  - DOCUMENTATION INVENTORY

SCHEDULING ASSISTANCE

- **COMPUTER – ASSISTED SCHEDULING**
- **COMPUTER ALGORITHM ADVISES LATEST DATE GIVEN:**
  - DESIRED COMPLETION DATE
  - LABOR CONTENT
  - UNATTENDED PROCESS TIME
  - SHOP CAPACITY
- **WORKLOAD FORECAST DISPLAYS AVAILABLE TO ASSIST**
- **KEY EVENT DATES AND JOB LISTS AVAILABLE**
- **TO BE ADDED : DYNAMIC PERT / CMP ANALYSIS**

ETV APPLICABILITY TO SHIPYARD REPAIR PROCESSES

- NO CONCEPTUAL DIFFERENCES WHATSOEVER
- SAME MANAGEMENT PROCESSES
- DIFFERENCES IN FACILITY SIZE & ORGANIZATION
- JOBS LARGER AND LAST LONGER THAN IMA BUT SIMILAR SHOPS/WORK
- NEED LARGER, MORE EXTENSIVE COMPUTER SYSTEM
- LABOR COSTS AND OVERHEAD COSTS NOT CAPTURED IN IMA
- ENHANCED ETV SYSTEM COULD BE VALIDATED AS A FULL CCSS

SOME FINAL THOUGHTS –
IT'S GREAT,
BUT:

- **EARNED HOUR SYSTEM NECESSITATES LABOR STANDARDS**

  - NO. A MIX OF STANDARDS, ESTIMATES AND ALLOWANCES IS OK. HOWEVER, THE MORE STANDARDS THE BETTER.

- **WORK FORCE RESISTS STANDARDS**

  - NO. A STANDARD IS A REASONABLE GOAL BUT NOT A QUOTA. IT'S UP TO MANAGEMENT.

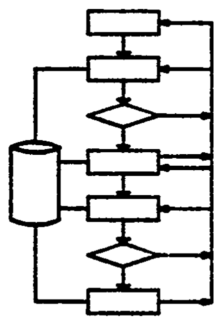
- **FOREMAN AND GROUP SUPERVISORS WILL RESIST THE COMPUTER**

  - NONSENSE. THE OPPOSITE IS TRUE.
    IT SEDUCES THEM !

MATERIAL REQUIREMENTS PLANNING - A NEW AUTOMATED SYSTEM

AT THE LONG BEACH NAVAL SHIPYARD

CLOSED LOOP MRP
BRINGS MATERIAL
JUST IN TIME!



Presented By
Douglas W• Cunningham
Arthur Andersen & Co.
Los Angeles, California
(213) 614-6558

Mr. Cunningham is a senior manager with Arthur Andersen & Co.S Management Information Consulting Division. He specializes in the planning, design and installation of information systems for the Department of Defense and for manufacturing companies. For the past three years Mr. Cunningham has been the manager of a large project with NAVSEA and the Long Beach Naval Shipyard to tailor Arthur Andersen & Co.'s MRP system to the ship overhaul and repair environment.

Mr. Cunningham has a Bachelor of Science degree in computer science and an MBA from UCLA. He lectures regularly at UCLA's Graduate School of Management on information systems management.

Acknowledgement

This paper presents information developed as a part of a joint project performed by LBNSY and Arthur Andersen & Co. The project was initiated and performed under the outstanding leadership of Bernie Austin, Larry Vivien and Helen Reed at the Long Beach Naval Shipyard and Mitch Scippioni and Dale Blevins from NAVSEA.

The statements made here are the views of Mr. Cunningham and may not represent the views of LBNSY or NAVSEA .

Abstract

A new on-line, minicomputer-based Material Requirements Planning (MRP) system is helping the Long Beach Naval Shipyard (LBNSY) plan and control material in the Marine Machine Shop. The system features proven, state-of-the-art management techniques transferred from highly successful American and Japanese manufacturing companies and fitted to the repair and overhaul environment at LBNSY. The large, measured benefits include fewer material shortages, less surplus, reduced turnaround time to overhaul a component and improved control over previously unrecorded (goldpile) material.

The system helps both planning and production personnel by:

1. Effectively anticipating material requirements in advance of need.

2. Predicting part usage based on historical usage of parts per overhaul.

3. Developing time-phased net material requirements based on scheduled overhauls and expected usage, on-hand and on-order position, safety stock levels and lead times.

4. Assisting in analyzing the impact of changes in the overhaul schedule.

5. Providing easy-to-use, on-line, integrated access to information.

Current activities include implementing other shops, adding capacity planning and shop floor control functions and fully integrating the system into the shipyard's overall system concept, the Shipyard Repair Management System. MRP is the wave of the future and LBNSY will be there!

Background

In the mid-1970's LBNSY prepared a shipyard modernization program to upgrade facilities and systems to support the fleet of the future. The Shipyard was already experiencing a shift from doing repair work aboard ship to doing much repair work in its shops. The modernization program included an information system that introduced management techniques that had been proven successful in the manufacturing industry but which were untried in the ship overhaul environment. These techniques are known as Manufacturing Resource Planning (MRP II) techniques.

During 1980 and 1981 LBNS and Arthur Andersen & Co. conducted a pilot project to test MRP II techniques as to their applicability to ship overhauls. The Marine Machine Shop (Shop 38) was used as the pilot shop. Arthur Andersen & Co.'s MAC-PAC (Manufacturing Planning and Control) software package was chosen by LBNSY and implemented as the pilot software. The pilot project evaluation showed that very substantial benefits could be achieved with MRP II, particularly regarding the reduction of shortages.

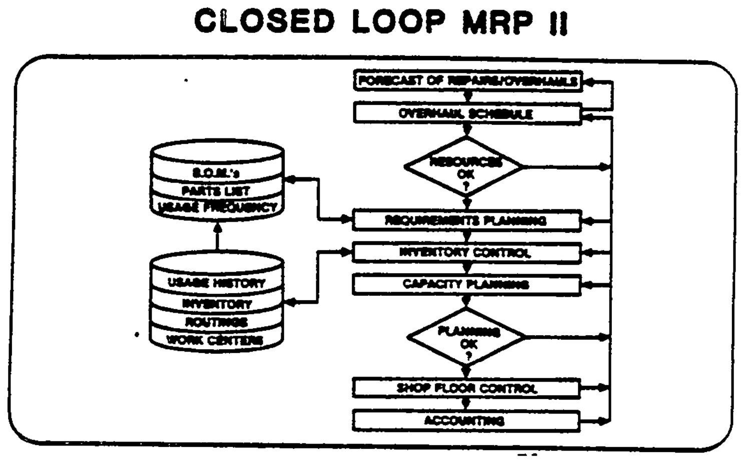
LBNSY then decided to implement the material-related, material requirements planning functions of MRP II in the other large, high-benefit shops in the Shipyard. The shop floor tracking and detailed capacity planning functions of MRP II were deferred until recently when a design project was initiated. In this paper MRP refers to the Material Requirements Planning functions of the broader Manufacturing Resource Planning (MRP II) system.

SYstem Functions

Closed-loop MRP II is a proven, comprehensive approach to planning and controlling all resources (material, tools, labor, machinery and facilities) required to support a shipyard's overall mission. The term "closed-loop" means that there is timely feedback between the execution and planning functions, which helps to ensure proper actions are taken when changes in either plans or execution occur.

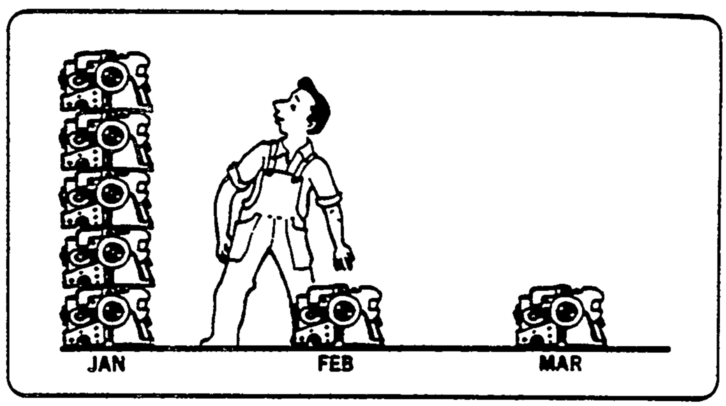
Figure 1. is the anchor chart for this paper and depicts the flow of MRP II. Brief descriptions of the functions within the closed-loop system are included below:

Figure 1.



<u>Forecasts of Repairs/Overhauls</u>--LBNSY receives and develops forecasts of components to be repaired from SPCC, other shipyards, and from ships planned for overhaul. The components to be overhauled are scheduled by quarter, up to a year or more in the future. (See Figure 2.)

Figure 2.

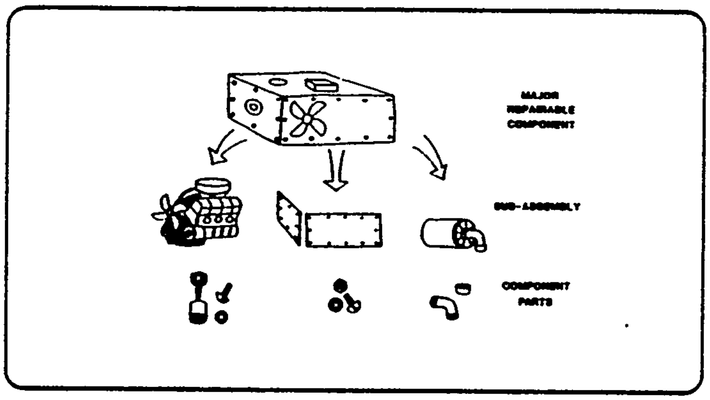


<u>Overhaul Schedule</u>--Planning and Estimating personnel use the quarterly schedules to develop and enter a master Overhaul Schedule into the system. The Overhaul Schedule identifies the week in which the components are planned to be overhauled. A preliminary Overhaul Schedule is determined by weighing rough-cut labor and machine resource availability against the scheduled workload. Adjustments to the Overhaul Schedule are made until the schedule is balanced.

Data Base--The data base is the backbone of MRP II. The data base includes simplified bills of material (which describe the parts likely to be used in the overhaul, see Figure 3.), parts list (for components whose bill of material is cumbersome or non-critical), usage frequency statistics (describing the likelihood or probability of replacing each piece part during a given overhaul), usage history, inventory on-hand and on-order balances, and routing and work center data. The data is maintained on-line with good security, controls and audit trails to help assure accuracy and timeliness.

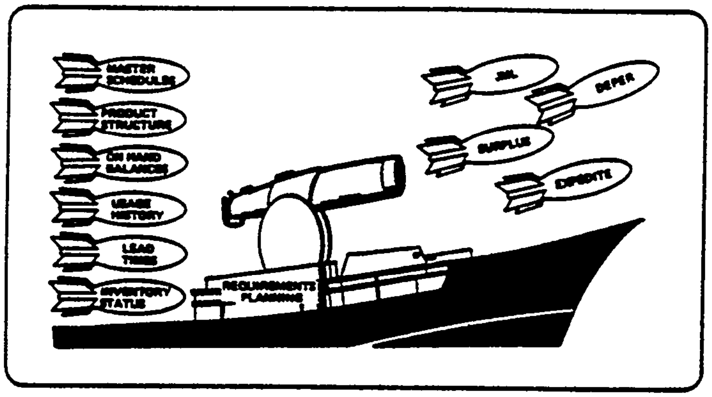
SIMPLE BILLS OF MATERIAL OR PART LISTS

Figure 3.



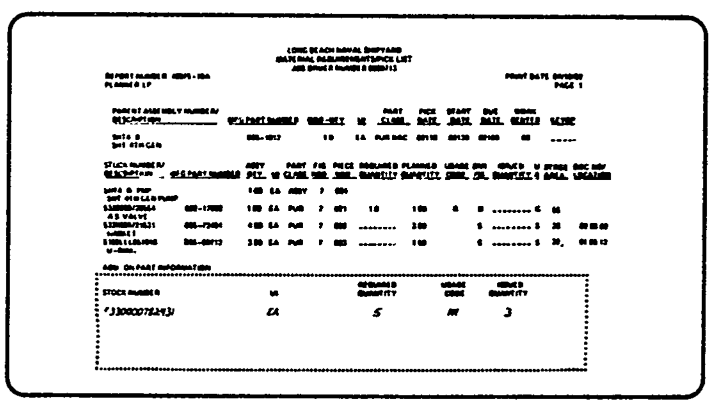
Requirements Planning--This is the heart of MRP. Requirements Planning analyzes the (1) Overhaul Schedule (2) bill of material or parts list for each component in the master schedule, (3) on-hand inventory balance of each part required, (4) outstanding purchase requisitions and (5) acquisition lead times to develop time-phased net material requirements. The system recommends to the planners specific actions to correct anticipated surplus or shortage conditions. These recommendations include creating, deferring, canceling or expediting job material lists (JMLs) or shop stores requisitions. (See Figure 4.) The JMLs and requisitions launched by the system attempt to have the right material, in the right quantities, at the right place, to meet the Overhaul Schedule.

Figure 4•



Inventory Control--Keeping accurate on-hand balances and location of material is the purpose of Inventory Control. When a mechanic starts on a job order, he has a Material Requirements/Pick List (see Figure 5). The Pick List identifies the material the mechanic will likely need to do the overhaul, by both National Stock Number and manufacturer's part number. The mechanic simply fills in how many of each part he actually needs, based on his inspection. Items replaced 100% of the time are identified as such. The Pick List is then reviewed by the foreman (a convenient quality assurance step to make sure only the necessary, and all the necessary, parts are being requested). Then, the Pick List is handed to a storekeeper for picking and entering into the system.

Figure 5.



All issues, receipts, adjustments and movement of inventory are recorded. Each part's actual usage history is maintained to refine the usage frequency utilized for part planning and ordering.

Capacity Planning--When implemented, Capacity Planning will be used for detailed loading of work centers, machines, test stands, employees, and other critical resources defined in the routing (job sequence). Good labor and machine standards are essential to Capacity Planning and LBNSY is aggressively developing and refining Engineered Methods and Standards documentation.

Shop Floor Control--When installed, the status of each job order will be communicated to shipyard management through the Shop Floor Control function. The labor and material used on each overhaul to date will be recorded to determine the stage of completion. This information will be used by shop planners and foremen to expedite material, prioritize resources, etc., to meet the scheduled due dates of job orders.

Accounting--From the detailed information collected in the inventory control and shop tracking functions, the accounting function accumulates the actual material and labor expended for each component overhauled. The dollar costs and performance variances for each overhaul are reported for analysis.

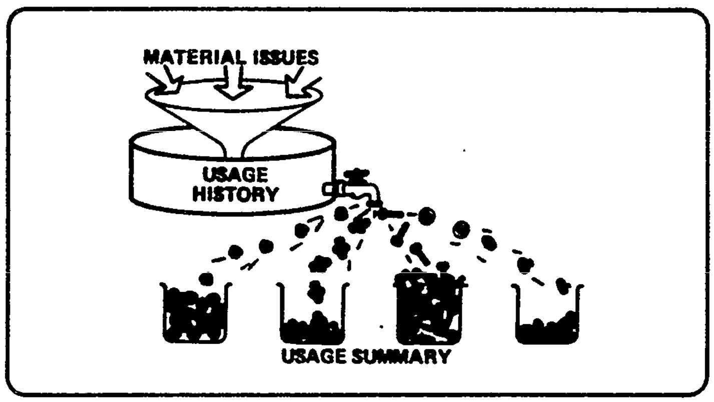
Usage Frequency

One of the unique elements of material requirements planning in a repair and overhaul environment is usage frequency. Usage frequency refers to the probability of replacing a particular piece part during the overhaul of a single master scheduled component. For example, if a pump bearing is replaced 60 times during overhauls of 100 pumps, the bearing would likely be assigned a usage frequency of 60%. If there were two identical pump bearings each with usage frequencies of 60%, requirements planning logic would multiply .60 x 2 and conclude that, on the average, 1.2 of the bearings are needed for each pump overhaul. When analyzing the overhaul schedule, the requirements planning logic rounds up and carries forward remainders so that only whole units are requisitioned.

Much statistical theory can be applied to the analysis of usage history (illustrated in Figure 6). Standard deviations and groupings of scheduled components

by ship may influence the planned gross requirement for a given part. To keep the system simple to use, LBNSY utilizes a mean as the usage frequency and sets appropriate safety stock levels to allow for the likely variations in usage frequency and lead time. Parts with 30% or greater usage frequency are treated as dependent demand items and are planned and controlled by requirements planning logic. Parts with under.301 usage frequency are treated as independent demand items and are planned and controlled using the reorder point logic of inventory control (Shipyard MIS MS logic).

Figure 6.



By anticipating the demand for parts through overhaul scheduling and forecasting, LBNSY has greatly improved their ability to deliver material "just-in-time". The MHP approach has proven to be much more effective and efficient than previous methods.

Technical Environment

The MHP system at LBNSY is Arthur Andersen & Co.'s commercially available MAC-PAC software package, tailored to the unique requirements of ship repair and overhaul. The system is programmed in COBOL, uses HP's IMAGE data base manager and, at LBNSY, runs on several Hewlett-Packard HP-3000 computers installed in Material Control Centers. The system has a unique screen handler which is based on character-mode, rather than block-mode, terminal communications, thus providing friendlier user conversations. Communications between HP-3000s is done via HP's DS-3000 software. Most conversations provide on-line validation and update, and response times are typically less than four seconds.

Interfaces between MRP and Shipyard MIS currently include material issues, receipts, movements, JMLs (order requisitions) and part master updates. An integration project is underway to merge the data bases of MRP and other LBNSY inventory systems, including a system which directly drives Kenway automated material storage and retrieval equipment. The HP-3000s have been linked to IBM personal computers for downloading and graphically displaying benefit achievement statistics. LBNSY will soon link the HP-1000 ARTEMIS repairables planning system to the overhaul scheduling portion of MRP, a very natural interface.

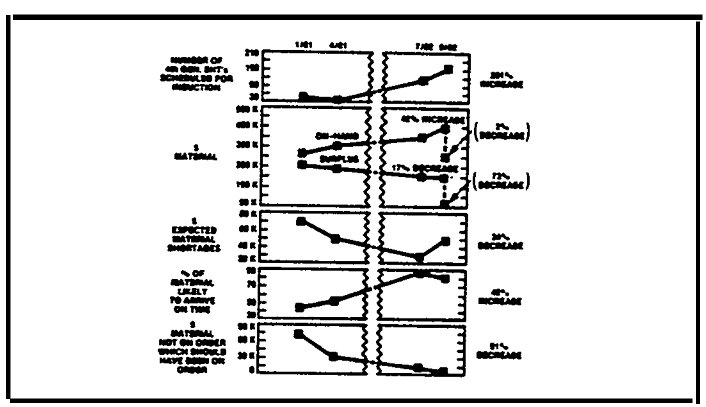
The technical environment is thought to be a model of how to integrate various brands of hardware and software. A great deal of technical system knowledge has been accumulated at LBNSY.

<u>Benefits</u>

The benefits derived during the MRP pilot project are striking. Figure 7. shows some of the results of that project. The charts show that, while the workload increased 281%, material on-hand increased only 42%. After the excess material identified by MRP was scrapped, material on-hand actually decreased. Surplus material decreased as material was issued and not reordered. Material shortages dropped dramatically as did material expected to arrive late.

LBNS
SHOP 38/08 MRP PILOT RESULTS

Figure 7.



A somewhat unexpected benefit of implementing MRP was the identification and control of large amounts of previously unrecorded assets (goldpile material). Thus far over 40% of the on-hand material being brought into the MRP system is like-new goldpile material. Thus LBNSY is getting control of massive amounts of previously informally controlled inventory.

Other areas which achieved improvements include reduced overtime, improved labor efficiency, reduced time spent expediting, improved quality of repair and reduced turnaround time.

An on-going benefits analysis is continuing to validate the tremendous advantages of MRP techniques. As more data is collected, LBNSY is better able to determine which components merit the effort to develop complete bills of material and precise usage frequency statistics and which components require only simple parts lists and roughly estimated usage frequencies. LBNSY is lowering the cost of creating the initial MRP data base by using Defense Logistics Service Center (DLSC) supplied part data. Thus, LBNSY is sharpening its ability to achieve benefits while simultaneously reducing the investment cost.

Summary

MRP is a powerful, leading-edge tool for managing material in a Navy shipyard. It is a comprehensive, understandable system, which meets the needs of production shop, planning and supply department users. MRP II, with material, shop tracking and capacity planning, is the future for Navy yards. MRP and MRP II are musts for the Navy to keep pace with its competition, you, the private shipyard!

LBNSY and Arthur Andersen & Co. have seen the opportunity for faster overhauls, with high quality, for less cost. We are convinced of the benefit potential and are dedicated to pursuing success with all our energy.